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IDENTIFIERS	Military Curriculum Project

ABSTRACT

These curriculum materials are the second section of a four-part, secondary-postsecondary-level course in metals processing. The course is one of a number of military-developed curriculum packages selected for adaptation to vocational instruction and curriculum development in a civilian setting. Block III, Introduction to Metallic Arc Welding, contains six lessons including fifty-eight hours of instruction: Principles of Operation and Maintenance of Arc Welding Machines, Identification and Selection of Electrodes, Stringer Beads and Building Up Worn Surfaces, Fillet Welds in the Flat and Horizontal Positions, Butt Joints of Carbon Steel Plate, and Butt Joints of Carbon Steel Sheet. Block IV, Special Metallic Arts and Resistance Welding Applications, contains six lessons covering fifty-eight hours of instruction: Fillet Welds in the Vertical Position, Fillet Welds in the Overhead Position, Pipe Joints, Heat and Corrosion Resistant Ferrous Alloys, Cast Iron, and Hard Surfacing, Cutting, and Resistance Welding. Instructor materials include a course chart, detailed lesson plans, and a plan of instruction containing the units of instruction, criterion objectives, and additional materials needed. Student materials include a study guide for each block that contains objectives, information, review exercises, and references for each lesson. Suggested audiovisuals are not provided. (YLB)

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Military Curricula for Vocational & Technical Education

METALS PROCESSING SPECIALIST
BLOCKS III & IV

U.S. DEPARTMENT OF HEALTH, EDUCATION & WELFARE
NATIONAL INSTITUTE OF EDUCATION

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THE NATIONAL CENTER
FOR RESEARCH IN VOCATIONAL EDUCATION
THE OHIO STATE UNIVERSITY

MILITARY CURRICULUM MATERIALS

The military-developed curriculum materials in this course package were selected by the National Center for Research in Vocational Education Military Curriculum Project for dissemination to the six regional Curriculum Coordination Centers and other instructional materials agencies. The purpose of disseminating these courses was to make curriculum materials developed by the military more accessible to vocational educators in the civilian setting.

The course materials were acquired, evaluated by project staff and practitioners in the field, and prepared for dissemination. Materials which were specific to the military were deleted, copyrighted materials were either omitted or approval for their use was obtained. These course packages contain curriculum resource materials which can be adapted to support vocational instruction and curriculum development.

The National Center Mission Statement

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- Generating knowledge through research
- Developing educational programs and products
- Evaluating individual program needs and outcomes
- Installing educational programs and products
- Operating information systems and services
- Conducting leadership development and training programs

FOR FURTHER INFORMATION ABOUT
Military Curriculum Materials
WRITE OR CALL

Program Information Office
The National Center for Research in Vocational Education
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Military Curriculum Materials for Vocational and Technical Education

Information and Field Services Division

The National Center for Research in Vocational Education

Military Curriculum Materials Dissemination Is . . .

an activity to increase the accessibility of military-developed curriculum materials to vocational and technical educators.

This project, funded by the U.S. Office of Education, includes the identification and acquisition of curriculum materials in print form from the Coast Guard, Air Force, Army, Marine Corps and Navy.

Access to military curriculum materials is provided through a "Joint Memorandum of Understanding" between the U.S. Office of Education and the Department of Defense.

The acquired materials are reviewed by staff and subject matter specialists, and courses deemed applicable to vocational and technical education are selected for dissemination.

The National Center for Research in Vocational Education is the U.S. Office of Education's designated representative to acquire the materials and conduct the project activities.

Project Staff:

Wesley E. Budke, Ph.D., Director
National Center Clearinghouse

Shirley A. Chase, Ph.D.
Project Director

What Materials Are Available?

One hundred twenty courses on microfiche (thirteen in paper form) and descriptions of each have been provided to the vocational Curriculum Coordination Centers and other instructional materials agencies for dissemination.

Course materials include programmed instruction, curriculum outlines, instructor guides, student workbooks and technical manuals.

The 120 courses represent the following sixteen vocational subject areas:

- Agriculture
- Aviation
- Building & Construction Trades
- Clerical Occupations
- Communications
- Drafting
- Electronics
- Engine Mechanics
- Food Service
- Health
- Heating & Air Conditioning
- Machine Shop
- Management & Supervision
- Meteorology & Navigation
- Photography
- Public Service

The number of courses and the subject areas represented will expand as additional materials with application to vocational and technical education are identified and selected for dissemination.

How Can These Materials Be Obtained?

Contact the Curriculum Coordination Center in your region for information on obtaining materials (e.g., availability and cost). They will respond to your request directly or refer you to an instructional materials agency closer to you.

CURRICULUM COORDINATION CENTERS

EAST CENTRAL
Rebecca S. Douglass
Director
100 North First Street
Springfield, IL 62777
217/782-0759

NORTHWEST
William Daniels
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Building 17
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Olympia, WA 98504
206/753-0879

MIDWEST
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1515 West Sixth Ave.
Stillwater, OK 74704
405/377-2000

SOUTHEAST
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Mississippi State University
Drawer DX
Mississippi State, MS 39762
601/325-2510

NORTHEAST
Joseph F. Kelly, Ph.D.
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225 West State Street
Trenton, NJ 08625
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WESTERN
Lawrence F. H. Zane, Ph.D.
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1776 University Ave.
Honolulu, HI 96822
808/948-7834

Developed by:

United States Air Force

Development and Review Dates:

September 23, 1975

Occupational Area:
Machine Shop

Target Audiences:
Grades 11-adult

Print Pages:
207

Cost:
$4.25

Availability:
Military Curriculum Project, The Center for Vocational Education, 1960 Kenny Rd., Columbus, OH 43210

Contents:

Contents:	Type of Materials: Lesson Plans:	Programmed Text:	Student Workbook:	Handouts:	Text Materials:	Audio-Visuals:	Instructional Design: Performance Objectives:	Tests:	Review Exercises:	Additional Materials Required:	Type of Instruction: Group Instruction:	Individualized:
Block III — *Introduction to Metallic Arc Welding*								★				
Principles of Operation and Maintenance of Arc Welding Machines	•				•	★	•		•	★	•	
Identification and Selection of Electrodes	•				•	★	•		•	★	•	
Stringer Beads and Building Up Worn Surfaces	•				•		•		•	★	•	
Fillet Welds in the Flat and Horizontal Positions	•				•		•		•	★	•	
Butt Joints of Carbon Steel Plate	•				•	★	•		•	★	•	
Butt Joints of Carbon Steel Sheet	•				•	★	•		•	★	•	
Block IV — *Special Metallic Arc and Resistance Welding Applications*												
Fillet Welds in the Vertical Position	•				•		•		•	★	•	
Fillet Welds in the Overhead Position	•				•		•		•	★	•	
Pipe Joints	•				•	★	•		•	★	•	
Heat and Corrosion Resistant Ferrous Alloys	•				•		•		•	★	•	
Cast Iron	•				•		•		•	★	•	
Hard Surfacing, Cutting and Resistance Welding	•				•		•		•	★	•	

★ Materials are recommended but not provided.

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Expires July 1, 1978

Course Description:

This is the second section of a four-part course on metals processing. Training for the entire course includes fabrication of welded structures and metal weld repairs; principles, techniques and processes of welding, cutting, soldering, brazing, and hard surfacing of various types of metals used in the fabrication and repair of equipment; blueprint reading; heat treating, hardness testing, identification and prevention of corrosion; use of hand and measuring tools; and operation and maintenance of welding, heat treating, test equipment and power machinery such as grinders, drill presses, power saws, and metal cutting shears. Safety is emphasized throughout the course. This section deals with metallic arc welding, special metallic arc welding, and resistance welding applications covering 116 hours of instruction. Students should complete **Metals Processing Specialist, Blocks I & II (13-5)** before beginning this second part of the course.

Block III — *Introduction to Metallic Arc Welding* contains six lessons including 58 hours of instruction. The lesson topics and respective hours follow:

Principles of Operation and Maintenance of Arc Welding Machines (3 hours)
Identification and Selection of Electrodes (4 hours)
Stringer Beads and Building Up Worn Surfaces (6 hours)
Fillet Welds in the Flat and Horizontal Positions (14 hours)
Butt Joints of Carbon Steel Plate (15 hours)
Butt Joints of Carbon Steel Sheet (16 hours)

Block IV — *Special Metallic Arc and Resistance Welding Applications* contains six lessons covering 58 hours of instruction.

Fillet Welds in the Vertical Position (12 hours)
Fillet Welds in the Overhead Position (18 hours)
Pipe Joints (6 hours)
Heat and Corrosion Resistant Ferrous Alloys (8 hours)
Cast Iron (4 hours)
Hard Surfacing, Cutting, and Resistance Welding (10 hours)

This section contains both teacher and student materials. Printed instructor materials include a course chart; detailed lesson plans; and a plan of instruction including the units of instruction, criterion objectives, the duration of the lessons, and additional materials needed. Student materials include a study guide for each block which contains objectives, information, review exercises, and references for each lesson.

Text materials are provided in the student study guides, however, several commercial texts and military technical manuals are referenced throughout the course. Audiovisuals suggested for use in the entire course include 188 slides, 8 films, 2 videotapes, and 9 transparency sets. The audiovisuals are not provided.

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THE OHIO STATE UNIVERSITY

METALS PROCESSING SPECIALIST, BLOCKS III & IV

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COURSE CHART - TABLE II - TRAINING CONTENT

NOTE: Include time spent on technical training (TT) (classroom / laboratory (C/L)) and complementary technical training (CTT) and related training (RT). Exclude time spent on individual assistance (remedial instruction). A single entry of time shown for a unit is C/L time. When a double entry is shown, the second entry is CTT time.

WK OF TNG \ HRS PER DAY	1 2 3 4 5 6	7 8
	Course Material - UNCLASSIFIED — 80 Hours TT BLOCK III - Introduction to Metallic Arc Welding	20 Hours CTT
5 6	Principles of Operation and Maintenance of Arc Welding Machines (3 hrs); Identification and Selection of Electrodes (4 hrs); Stringer Beads and Building up Worn Surfaces (6 hrs); Fillet Welds in the Flat and Horizontal Positions (14 hrs); Butt Joints of Carbon Steel Plate (15 hrs); Butt Joints of Carbon Steel Sheet (16 hrs); Measurement and Critique (2 hrs). (Equipment Hazards and Personnel Safety Integrated with Above Subjects)	
	60 Hours C/L	
	Course Material - UNCLASSIFIED — 78 Hours TT BLOCK IV - Special Metallic Arc and Resistance Welding Applications	18 Hours CTT
7 8	Fillet Welds in the Vertical Position (12 hrs); Fillet Welds in the Overhead Position (18 hrs); Pipe Joints (6 hrs); Heat and Corrosion Resistant Ferrous Alloys (8 hrs); Cast Iron (4 hrs); Hard Surfacing, Cutting, and Resistance Welding (10 hrs); Measurement and Critique (2 hrs). (Equipment Hazards and Personnel Safety Integrated with Above Subjects)	2 Hours RT
	60 Hours C/L	

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PLAN OF INSTRUCTION	COURSE TITLE: Metals Processing Specialist

BLOCK TITLE: Introduction to Metallic Arc Welding

1 UNITS OF INSTRUCTION AND CRITERION OBJECTIVES	2 DURATION (HOURS)	3 SUPPORT MATERIALS AND GUIDANCE
1. Principles of Operation and Maintenance of Arc Welding Machines a. Without reference, state the principles of operation and uses of arc welding machines with 75% accuracy. b. Given equipment, while observing all shop safety, set up and adjust an arc welding machine preparatory to welding IAW TO 34W4-1-5. c. Given equipment, while observing all shop safety, perform operator maintenance of arc welding machines IAW TO 34W4-1-5.	5 (3/2)	Column 1 Reference — STS Reference 1a — 22a 1b — 3b, 22b 1c — 3b, 22c Instructional Materials 3ABR53131-SG-301, Principles of Operation and Maintenance of Arc Welding Machines TO 34W4-1-5, Welding Theory and Application Modern Welding (Chapter 6) Audio Visual Aids Chart: Arc Welding Machine Controls Training Equipment Arc Welding Equipment consisting of: Booth, Electric Arc Welding Machine, Protective Equipment, Arc Welding Cables, and Welding Table (1) Trainer: 3218, Electrical Weld (12) Trainer: 3219, Electrical (12) Toolkit (1) Training Methods Discussion/Demonstration (1.5 hrs) Performance (1.5 hrs) Outside Assignment (2 hrs) Instructional Environment/Design Classroom (1 hr) Laboratory (2 hrs) Instructional Guidance Emphasize importance of correct machine adjustment and discuss shop safety applicable to arc welding equipment. Make outside assignment to read 3ABR53131-SG-302 and Chapter 6, para 15 thru 23, Modern Welding. Administer appraisal test upon completion of this assignment. Caution

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PLAN OF INSTRUCTION (Continued)

1 UNITS OF INSTRUCTION AND CRITERION OBJECTIVES	2 DURATION (HOURS)	3 SUPPORT MATERIALS AND GUIDANCE
2. Identification and Selection of Electrodes a. Given military specifications, select and identify the types of arc welding electrodes without error. b. Given AWS numerical and color coded systems, select and identify the types of arc welding electrodes without error.	6 (4/2)	students not to mark or write on any training literature as it is to be reused by subsequent classes. Column 1 Reference — STS Reference 2a — 22d 2b — 22c Instructional Materials 3ABR53131-SG-302, Identification and Selection of Electrodes TO 34W4-1-8, Use of Welding, Brazing, and Silver Soldering Electrodes, Rods and Wires TO 34W4-1-5 Modern Welding (Chapter 6) Audio Visual Aids Chart: Color Code Classification of Electrodes Training Methods Discussion (1 hr) Performance (3 hrs) Outside Assignment (2 hrs) Instructional Environment/Design Classroom (1 hr) Laboratory (3 hrs) Instructional Guidance Emphasize the importance of the correct selection and use of electrodes. Explain the class codes and color markings of the various electrodes. Make outside assignment to read 3ABR53131-SG-303 and Chapter 5, para 11, Modern Welding. Administer appraisal test upon completion of this assignment.

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PLAN OF INSTRUCTION (Continued)

1 UNITS OF INSTRUCTION AND CRITERION OBJECTIVES	2 DURATION (HOURS)	3 SUPPORT MATERIALS AND GUIDANCE
3. Stringer Beads and Building Up Worn Surfaces a. Given metallic arc welding equipment and carbon steel specimens, set up and employ proper welding techniques in building up flat and worn surfaces, free of undercut, overlap, and slag inclusions for a total combined distance of no less than 3/4 of the length of the specimen, excluding the first 1/2 inch start and the last 1/2 inch finish. All shop safety, good housekeeping, and fire prevention measures must be observed.	8 (6/2)	Column 1 Reference: 3a STS Reference: 3a, 3b, 22e Instructional Materials 3ABR53131-SG-303, Stringer Beads and Building Up Worn Surfaces TO 34W4-1-5 Modern Welding (Chapter 5) Training Equipment Arc Welding Booth Complete (1) Toolkit (1) Training Methods Discussion/Demonstration (1 hr) Performance (5 hrs) Outside Assignment (2 hrs) Instructional Environment/Design Classroom (.5 hr) Laboratory (5.5 hrs) Instructional Guidance Emphasize safety in the operation of arc welding equipment. Discuss welding techniques in building up flat and worn surfaces. Make outside assignment to read 3ABR53131-SG-304 and Chapter 5, Modern Welding. Administer appraisal test upon completion of this assignment. Instructor will use "Quality and Reliability Assurance Handbook H-56, Arc Welding" (Chapter 4), as an additional reference throughout Block III. Emphasize conservation of electrodes - maximum length of 2-inch stubs.

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PLAN OF INSTRUCTION (Continued)

1 UNITS OF INSTRUCTION AND CRITERION OBJECTIVES	2 DURATION (HOURS)	3 SUPPORT MATERIALS AND GUIDANCE
4. Fillet Welds in the Flat and Horizontal Position a. Given metallic arc welding equipment and carbon steel sheet specimens, set up and make fillet welds in the flat position, free of excessive penetration, overlap, undercut, and slag inclusions for a total combined distance of no less than 3/4 of the length of the specimen excluding the first 1/2 inch start and the last 1/2 inch finish. All shop safety, good housekeeping, and fire prevention measures must be observed. b. Given metallic arc welding equipment and carbon steel sheet specimens, set up and make fillet welds in the horizontal position, free of excessive penetration, overlap, undercut, and slag inclusions for a total combined distance of no less than 3/4 of the length of the specimen, excluding the first 1/2 inch start and the last 1/2 inch finish. All shop safety, good housekeeping, and fire prevention measures must be observed.	18 (14/4) (7) (7)	Column 1 Reference — STS Reference 4a — 3a, 3b, 22j 4b — 3a, 3b, 22k Instructional Materials 3ABR53131-SG-304, Fillet Welds in the Flat and Horizontal Position TO 34W4-1-5 Modern Welding (Chapter 5) Training Equipment Arc Welding Booth Complete (1) Toolkit (1) Training Methods Discussion/Demonstration (3 hrs) Performance (11 hrs) Outside Assignment (4 hrs) Instructional Environment/Design Classroom (2 hrs) Laboratory (12 hrs) Instructional Guidance Emphasize welding safety and explain the requirements for fillet welds. Have each student clean each bead prior to the next pass. Make outside assignment to read 3ABR53131-SG-305 and Chapter 5, Modern Welding. Administer appraisal test upon completion of this assignment. Emphasize conservation of heavy plate.

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PLAN OF INSTRUCTION (Continued)

1 UNITS OF INSTRUCTION AND CRITERION OBJECTIVES	2 DURATION (HOURS)	3 SUPPORT MATERIALS AND GUIDANCE
5. Butt Joints of Carbon Steel Plate	19	Column 1 Reference / STS Reference 5a / 3a, 3b, 22f 5b / 22g 5c / 3a, 3b, 22h
a. Given power shears, grinding equipment, and metal specimens, set up and prepare joints for welding IAW TO 34W4-1-5. All shop safety, good housekeeping, and fire prevention measures must be observed.	(15/4) (.5)	Instructional Materials 3ABR53131-SG-305, Butt Joints of Carbon Steel Plate TO 34W4-1-5
b. Using a list of statements, select weld specification limits pertaining to welding plate with 75% accuracy.	(.5)	Modern Welding (Chapter 5) Audio Visual Aids Film: FLC 16-203, Prevention and Control of Manual Arc Weld
c. Given metallic arc welding equipment and carbon steel plate specimens, set up and weld butt joints in the flat position with 100% penetration, free of undercut, overlap, and slag inclusions, for a total combined distance of no less than 3/4 of the length of the specimen excluding the first 1/2 inch start and the last 1/2 inch finish. All shop safety, good housekeeping, and fire prevention measures must be observed.	(14)	Training Equipment Arc Welding Booth Complete (1) Grinders (4) Tensile Tester (12) Trainer: 3218 Electrical Weld (12) Power Shears (6) Toolkit (1) Training Methods Discussion/Demonstration (1 hr) Performance (14 hrs) Outside Assignment (4 hrs) Instructional Environment/Design Classroom (.5 hr) Laboratory (14.5 hrs) Instructional Guidance Emphasize safety in the use of power shears and grinders. Explain the weld requirements for heavy steel plate butt joints. Make outside assignment to read 3ABR53131-SG-306 and Chapter 5, Modern Welding. Administer appraisal test upon completion of this assignment. Instructor will utilize tensile tester to pull welded coupons. Emphasize conservation of large diamter electrodes.

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PLAN OF INSTRUCTION (Continued)

1 UNITS OF INSTRUCTION AND CRITERION OBJECTIVES	2 DURATION (HOURS)	3 SUPPORT MATERIALS AND GUIDANCE
6. Butt Joints of Carbon Steel Sheet a. Given metallic arc welding equipment and light gauge carbon steel sheet specimens, set up and weld butt joints in the flat position, with 100% penetration, free of undercut, overlap, and slag inclusions for a total combined distance of no less than 3/4 of the length of the specimen, excluding the first 1/2 inch start and the last 1/2 inch finish. All shop safety, good housekeeping, and fire prevention measures must be observed. b. Given metallic arc welding equipment and heavy carbon steel sheet specimens, set up and weld butt joints in the flat position, with 100% penetration, free of undercut, overlap, and slag inclusions for a total combined distance of no less than 3/4 of the length of the specimen, excluding the first 1/2 inch start and the last 1/2 inch finish. All shop safety, good housekeeping, and fire prevention measures must be observed. 7. Measurement and Critique	22 (16/6) (6) (10) 2	Column 1 Reference — STS Reference 6a — 3a, 3b, 22i 6b — 3a, 3b, 22h Instructional Materials 3ABR53131-SG-306, Butt Joints of Carbon Steel Sheet TO 34W4-1-5 Modern Welding (Chapter 5) Audio Visual Aids Slides: Butt Joints Training Equipment Arc Welding Booth Complete (1) Grinders (4) Power Shears (6) Trainer: 3218 Electrical Weld (12) Toolkit (1) Training Methods Discussion/Demonstration (2 hrs) Performance (14 hrs) Outside Assignment (6 hrs) Instructional Environment/Design Classroom (1 hr) Laboratory (15 hrs) Instructional Guidance Emphasize safety in the use of power shears and grinders. Explain the weld requirements for butt joints of steel sheet. Make outside assignment to read 3ABR53131-SG-401 and Chapter 5, Modern Welding. Administer appraisal test upon completion of this assignment. Emphasize proper joint spacing to conserve filler rod.

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PLAN OF INSTRUCTION	COURSE TITLE: Metals Processing Specialist

BLOCK TITLE: Special Metallic Arc and Resistance Welding Applications

1 UNITS OF INSTRUCTION AND CRITERION OBJECTIVES	2 DURATION (HOURS)	3 SUPPORT MATERIALS AND GUIDANCE
1. Fillet Welds in the Vertical Position a. Given metallic arc welding equipment and carbon steel plate specimens, set up and make fillet welds in the vertical position, free of undercut, overlap, and slag inclusions for a total combined distance of no less than 3/4 of the length of the specimen, excluding the first 1/2 inch start and the last 1/2 inch finish. All shop safety, good housekeeping, and fire prevention measures must be observed.	16 (12/4)	Column 1 Reference: 1a STS Reference: 3a, 3b, 221 Instructional Materials 3ABR53131-SG-401, Fillet Welds in the Vertical Position TO 34W4-1-5, Welding Theory and Application Modern Welding (Chapter 5) Training Equipment Arc Welding Booth Complete (1) Trainer: 3218 Electrical Weld (12) Power Shears (6) Toolkit (1) Training Methods Discussion/Demonstration (1 hr) Performance (11 hrs) Outside Assignment (4 hrs) Instructional Environment/Design Classroom (.5 hr) Laboratory (11.5 hrs) Instructional Guidance Emphasize welding safety applicable to vertical position welding. Explain weld requirements for fillet welds. Make outside assignment to read 3ABR53131-SG-402 and Chapter 5, Modern Welding. Administer appraisal test upon completion of this assignment. Caution students not to mark or write on any training literature as it is to be reused by subsequent classes. Stress maximum utilization of entire joint length.

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PLAN OF INSTRUCTION (Continued)

1 UNITS OF INSTRUCTION AND CRITERION OBJECTIVES	2 DURATION (HOURS)	3 SUPPORT MATERIALS AND GUIDANCE
2. Fillet Welds in the Overhead Position a. Given metallic arc welding equipment and carbon steel plate specimens, set up and make fillet welds in the overhead position, free of undercut, overlap, and slag inclusions for a total combined distance of no less than 3/4 of the specimen, excluding the first 1/2 inch start and the last 1/2 inch finish. All shop safety, good housekeeping, and fire prevention measures must be observed.	24 (18/6)	Colum 1 Reference: 2a STS Reference: 3a, 3b, 22m Instructional Materials 3ABR53131-SG-402, Fillet Welds in the Overhead Position TO 34W4-1-5 Modern Welding (Chapter 5) Training Equipment Arc Welding Booth Complete (1) Trainer: 3218 Electrical Weld (12) Power Shears (6) Toolkit (1) Training Methods Discussion/Demonstration (1 hr) Performance (17 hrs) Outside Assignment (6 hrs) Instructional Environment/Design Classroom (.5 hr) Laboratory (17.5 hrs) Instructional Guidance Emphasize welding safety applicable to overhead welding. Explain weld requirements for overhead position welding. Make outside assignment to read 3ABR53131-SG-403 and Chapter 18, para 60 thru 67, Modern Welding. Administer appraisal test upon completion of this assignment. Emphasize short arc length to conserve electrodes.

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PLAN OF INSTRUCTION (Continued)

1 UNITS OF INSTRUCTION AND CRITERION OBJECTIVES	2 DURATION (HOURS)	3 SUPPORT MATERIALS AND GUIDANCE
3. Pipe Joints a. Given metallic arc welding equipment and carbon steel pipe specimens, set up and weld pipe joints with 100% penetration, free of undercut, overlap, and slag inclusions, for a total combined distance of no less than 3/4 of the length of the weld. All shop safety, good housekeeping, and fire prevention measures must be observed.	8 (6/2)	Column 1 Reference 3a STS Reference 3a, 3b, 22n Instructional Materials 3ABR53131-SG-403, Pipe Joints TO 34W4-1-5 Modern Welding (Chapter 18) Audio Visual Aids Chart: Pipe Welding - Welding Sequences Training Equipment Arc Welding Booth Complete (1) Power Saw (12) Grinder (4) Toolkit (1) Training Methods Discussion/Demonstration (1 hr) Performance (5 hrs) Outside Assignment (2 hrs) Instructional Environment/Design Classroom (.5 hr) Laboratory (5.5 hrs) Instructional Guidance Emphasize welding safety and joint set-up procedures. Make outside assignment to read 3ABR53131-SG-404 and Chapter 18, para 13 thru 18, Modern Welding. Administer appraisal test upon completion of this assignment. Emphasize proper joint fit-up to conserve welding time and material.

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PLAN OF INSTRUCTION (Continued)

1 UNITS OF INSTRUCTION AND CRITERION OBJECTIVES	2 DURATION (HOURS)	3 SUPPORT MATERIALS AND GUIDANCE
4. Heat and Corrosion Resistant Ferrous Alloys a. Given metallic arc welding equipment and heat and corrosion resistant ferrous alloy specimens, set up and weld butt joints with 100% penetration, free of undercut, overlap, and slag inclusions for a total combined distance of no less than 3/4 of the length of the specimen, excluding the first 1/2 inch start and the last 1/2 inch finish. All shop safety, good housekeeping, and fire prevention measures must be observed.	10 (8/2)	Column 1 Reference: 4a STS Reference: 3a, 3b, 22o Instructional Materials 3ABR53131-SG-404, Heat and Corrosion Resistant Ferrous Alloys TO 34W4-1-5 Modern Welding (Chapter 18) Training Equipment Arc Welding Booth Complete (1) Power Shears (6) Toolkit (1) Training Methods Discussion/Demonstration (2 hrs) Performance (6 hrs) Outside Assignment (2 hrs) Instructional Environment/Design Classroom (1 hr) Laboratory (7 hrs) Instructional Guidance Emphasize welding safety and welding techniques for heat and corrosion resistant ferrous alloys. Make outside assignment to read 3ABR53131-SG-405 and Chapter 18, para 28 thru 31, Modern Welding. Administer appraisal test upon completion of this assignment. Emphasize conservation of heat and corrosion resistant ferrous alloys.

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PLAN OF INSTRUCTION NO. 3ABR53131	DATE 23 September 1975	BLOCK NO. IV	PAGE NO. 30

PLAN OF INSTRUCTION (Continued)

1 UNITS OF INSTRUCTION AND CRITERION OBJECTIVES	2 DURATION (HOURS)	3 SUPPORT MATERIALS AND GUIDANCE
5. Cast Iron a. Given metallic arc welding equipment and gray iron castings, set up and weld butt joints with 100% penetration, free of undercut, overlap, and slag inclusions, for a total combined distance of no less than 3/4 of the length of the specimen excluding the first 1/2 inch start and the last 1/2 inch finish. All shop safety, good housekeeping, and fire prevention measures must be observed.	6 (4/2)	Column 1 Reference: 5a STS Reference: 3a, 3b, 22q Instructional Materials 3ABR53131-SG-405, Cast Iron TO 34W4-1-5 Modern Welding (Chapter 18) Training Equipment Arc Welding Booth Complete (1) Power Saw (12) Grinders (4) Toolkit (1) Training Methods Discussion/Demonstration (1 hr) Performance (3 hrs) Outside Assignment (2 hrs) Instructional Environment/Design Classroom (.5 hr) Laboratory (3.5 hrs) Instructional Guidance Emphasize welding safety applicable to cast iron. Stress the importance of proper welding techniques for cast iron. Make outside assignment to read 3ABR53131-SG-406 and Chapters 9, 13, 14, and 20, Modern Welding. Administer appraisal test upon completion of this assignment. Emphasize conservation of cast iron and cast iron electrodes.

PLAN OF INSTRUCTION NO. 3ABR53131	DATE 23 September 1975	BLOCK NO. IV	PAGE NO. 31

PLAN OF INSTRUCTION (Continued)

1 UNITS OF INSTRUCTION AND CRITERION OBJECTIVES	2 DURATION (HOURS)	3 SUPPORT MATERIALS AND GUIDANCE
6. Hard Surfacing, Cutting, and Resistance Welding	12 (10/2)	Column 1 Reference / STS Reference 6a — 22p 6b — 22r 6c — 3a, 3b, 24a 6d — 3b, 24b 6e — 3b, 24c
a. Given a list, identify procedures pertaining to hard surfacing various metals with 75% accuracy.	(.5)	
b. Using a list, identify procedures relating to metallic arc cutting operations with 75% accuracy.	(.5)	Instructional Materials 3ABR53131-SG-406, Hard Surfacing, Cutting, and Resistance Welding TO 34W4-1-5 Modern Welding (Chapters 9, 13, 14, and 20)
c. Given welding equipment and ferrous and nonferrous metal specimens, set up and operate resistance spot welding equipment IAW Chapter 13 of Modern Welding. All shop safety, good housekeeping, and fire prevention measures must be observed.	(7)	Training Equipment Spot Welder (12) Foil Welder (3) Tensile Tester (12)
d. Given tensile test equipment and finished welds, while observing all shop safety, set up and test resistance spot welds for strength, porosity, nugget size, and shape. Two of three welds must conform to the proper strength requirements, nugget size, and shape, and be free of porosity IAW Chapter 13 and 14 of Modern Welding.	(1)	Training Methods Discussion/Demonstration (2 hrs) Performance (8 hrs) Outside Assignment (2 hrs) Instructional Environment/Design Classroom (1.5 hrs) Laboratory (8.5 hrs)
e. Given equipment, while observing all shop safety measures, perform operator maintenance of resistance spot welding machines IAW TO 34W4-1-5.	(1)	Instructional Guidance Emphasize safety in the operation of spot welding equipment and explain welding requirements for spot welds. Have student read 3ABR53131-SG-501 and Chapters 11 and 12, Modern Welding. Emphasize proper use and care of resistance welders and test equipment to reduce operational cost.
7. Related Training (identified in course chart).	2	
8. Measurement and Critique	2	

PLAN OF INSTRUCTION NO. 3ABR53131	DATE 23 September 1975	BLOCK NO. IV	PAGE NO. 32

LESSON PLAN (Part I, General)

APPROVAL OFFICE AND DATE: TWSTI 30 Sep 75	INSTRUCTOR: 13-6
COURSE NUMBER: 3ABR53131	COURSE TITLE: Metals Processing Specialist
BLOCK NUMBER: III	BLOCK TITLE: Introduction to Metallic Arc Welding
LESSON TITLE: Principles of Operation and Maintenance of Arc Welding Machines	

LESSON DURATION		
CLASSROOM /Laboratory: D & D 1.5 hrs/Perf 1.5 hrs	Complementary: NONE	TOTAL: (3) hrs

POI REFERENCE		
PAGE NUMBER: 21 and 22	PAGE DATE: 23 Sep 1975	PARAGRAPH: 1

STS/CTS REFERENCE	
NUMBER: STS 531X1	DATE: 31 May 1975

SUPERVISOR APPROVAL			
SIGNATURE	DATE	SIGNATURE	DATE

PRECLASS PREPARATION

EQUIPMENT LOCATED IN LABORATORY	EQUIPMENT FROM SUPPLY	CLASSIFIED MATERIAL	GRAPHIC AIDS AND UNCLASSIFIED MATERIAL
1. Arc Welding Equipment consisting of Booth, Electric Arc Welding Machine Protective Equipment, Arc Welding Cables and Welding Table.	Consolidated Toolkit	None	1. 3ABR53131-SG-301 2. TO 34W4-1-5 3. Modern Welding (Chapter 6) 4. Chart: CC74-225 Arc Welding Machine Controls

(cont on reverse) CRITERION OBJECTIVES AND TEACHING STEPS

a. Without reference, state the principles of operation and uses of arc welding machines with 75 percent accuracy.

b. Given equipment, while observing all shop safety, set up and adjust an arc welding machine preparatory to welding IAW TO 34W4-1-5.

c. Given equipment, while observing all shop safety, perform operator maintenance of arc welding machines IAW TO 34W4-1-5.

Teaching steps are listed in Part II.

EQUIPMENT LOCATED
IN LABORATORY (CONT)

2. Trainer 3218, Electrical Weld
3. Trainer 3219 Electrical

INTRODUCTION TIME: 10 Min

Attention:

Review: During your last lesson you learned and applied the fundamentals and principles of hard surfacing.

Overview: Upon completion of this lesson, students will learn the principles of operation and maintenance of arc welding machines.

Motivation:

BODY TIME: 2 hrs 40 min

Presentation:

Ref Objectives 1a, b and c.

1. Students will discuss and learn the principles of operation and use of electric arc welding machines.

a. Fundamentals of electricity:

(1) Electrical current has a positive and negative terminal or pole.

(2) Polarity is the direction of current or electron flow.

Demonstrate polarity and current flow on Trainer 3219 electrical.

(a) Straight polarity has the electrode negative, and the work positive.

(b) Reverse polarity has the electrode positive, and the work negative.

(3) Electric circuit--A complete conducting path over which an electric current flows.

(4) Electromotive Force (EMF) or volt--the push or pressure that moves the current.

(5) Ampere--the rate of electron or current flow past a given point per second.

(6) Ohm--the unit of resistance to current flow-calculated by voltage divided by current.

(7) Arc stream--A break or gap in an electric circuit which current flows or jumps across.

b. Types of welders:

(1) Transformer type AC welder

(a) Most commonly used AC welder.

(b) Most economical due to its lower initial cost and lower maintenance cost.

(c) Rated in amperses--100 to 1200 amps.

(d) Main parts include:

1. Transformer.

2. Frame.

3. Ventilating System.

4. Shell.

5. Adjusting Mechanism.

(2) AC-DC welding machines produce both currents through the use of a rectifier.

NOTE: Use Flip Chart #CC74-225

(3) DC Welders

(a) Driven by suitable motive power:

1. Gasoline engine.

2. Diesel engine.

3. Electric motor--most widely used DC welder in Air Force.

(b) Variable Voltage Type:

1. Automatic voltage control.

2. Manual amperage.

(c) Dual Control Type:

1. Manual voltage control.

2. Set up and adjust welding machine preparatory to welding.

Verify importance to proper set-up machine adjustment and welding by showing various welds located on Trainer 3218, Electrical Weld.

a. Current setting determined by:

(1) Size of electrode.

(2) Thickness of metal.

(3) Skill of operator--in general, the proper current settings are obtained from experience and should be adjusted to fulfill the requirements of the particular welding operation.

b. Forces responsible for metal deposition are:

(1) Gravity--the principle which accounts for the transfer of molten metal in the flat welding position.

(2) Gas Expansion--a gas produced by the burning of the electrode coating which expands from the heat at the electrode tip and helps to project the molten globules of metal and slag away from the electrode tip and into the molten pool.

(3) Electric Force--the force produced by the voltage across the arc that pulls the pinched off globule of metal into the molten pool regardless of welding position.

(4) Electromagnetic Force--the forces that produce a pinching effect on the metal globule and speeds the separation from the end of the electrode.

(5) Surface tension--the force which keeps the filler metal and slag in contact with the molten base metal in the arc crater.

c. Magnetic Arc Blow

(1) Erratic shifting of the arc.

(2) Induced by DC current.

(3) Overcome by:

(a) Changing position of the ground.

(b) Changing angle of the electrode.

(c) Change to AC as a last resort.

d. Major factors determining the the quality of the weld as outlined by the CLASS rule:

(1) Current setting.

(2) Length of arc.

(3) Angle of electrode.

(4) Speed of travel.

(5) Selection of electrode.

3. Perform operator maintenance of arc welding machines:

a. Before servicing an arc welding machine, all electricity must be turned off.

b. As used: check cables, ground and electrode holder.

c. Weekly: check for loose nuts, bolts, screws and parts.

d. Monthly: blow out all dust by using dry compressed air and remove all grease and oil residue.

e. Semi-annual: lubricate using only grease specified by the manufacturer.

f. Contact points that are pitted should be filed smooth.

g. Contact points that are badly burned will be replaced.

h. Major maintenance: to be performed by a qualified electrician only.

4. Safety Precautions:

a. While arc welding

(1) Eye protection

(2) Shock hazards

(3) Protective clothing

b. Shop area

(1) No horse play

(2) Handling of hot metal

(3) Proper use of machines and equipment

(4) Other safety precautions

Application:

1. Students will participate in making minor checks on arc welding machines concerning electrical contact points and cleaning.

2. Each student will receive a carbon steel plate 1/4" x 6 x 6 for practice on adjusting the machine and learning to get the arc started.

Evaluation:

1. Instructor will check students on their performance of their inspection, cleaning, setting up and using the electric arc welding machine and applicable equipment IAW 34W4-1-5.

2. Given a series of questions, students must answer correctly a minimum of 75% of all questions.

a. What is a dual control arc welding machine?

*An arc welding machine that has two separate manual controls for adjusting amperage and voltage.

b. How is the amperage controlled on a dual control machine?

* By a separate manual control.

c. How is the amperage controlled on a single control machine?

*By an automatic control.

d. How are the cables connected for Direct Current Straight Polarity?

*Electrode is negative; work is positive.

e. How are electrical contact points that are pitted serviced?

*By filing smooth

f. How is arc blow controlled?

*Either by changing position of ground, or changing angle of electrode.

g. How are the cables connected for Direct Current Reverse Polarity?

*Electrode is positive; work is negative.

h. What must be checked daily by a welder?

*Cables, ground and electrode holder

i. What is electric forces?

*The forces produced by voltage which pulls the globules of molten metal into the molten pool regardless of weld position.

j. What determines the type of grease to be used on welding machines?

*The type specified by the manufacturer.

k. What encourages the flow of electrons across the arc?

*Voltage or electromotive force

l. What effect does a long arc have?

*Spattering, loss of puddle control and poor penetration.

m. What is surface tension?

n. What are the amperage and voltage requirements of a welding machine?

*Low voltage and high amperage.

o. Where is the heat generated when arc welding?

*Between the end of the electrode and the base metal.

p. What determines the amperage setting?

*Size of electrode thickness of base metal skill and experience of welder.

q. What is the first step before performing maintenance on an arc welding machine?

*Disconnect electrical power.

CONCLUSION

Summary:

1. Fundamentals of electricity:
   a. Electrical Circuit.
   b. Electromotive Force (EMF).
   c. Ampere.
   d. Ohm.
   e. Arc Stream.
2. Types of welders:
   a. AC Transformer.
   b. AC-DC Rectified.
   c. DC Generator.

3. Set up and adjustment of welding machines:

   a. Current settings.

   b. Forces in the arc.

4. Operator Maintenance

Assignment:

1. Read 3ABR53131-SG-302.

2. Read MWHB, Chap 6, para 15-23.

Remotivation:

Closure:

LESSON PLAN (Part I, General)

APPROVAL OFFICE AND DATE: TWSTI 26 Sep 75	INSTRUCTOR:
COURSE NUMBER: 3ABR53131	COURSE TITLE: Metals Processing Specialist
BLOCK NUMBER: III	BLOCK TITLE: Introduction to Metallic Arc Welding

LESSON TITLE: Identification and Selection of Electrodes

LESSON DURATION

CLASSROOM/Laboratory	Complementary	TOTAL
D & D 1 hr/Perf 3 hrs	2hrs	6 hrs

POI REFERENCE

PAGE NUMBER	PAGE DATE	PARAGRAPH
22	23 Sep 1975	2

STS/CTS REFERENCE

NUMBER	DATE
STS 531X1	31 May 1975

SUPERVISOR APPROVAL

SIGNATURE	DATE	SIGNATURE	DATE

PRECLASS PREPARATION

EQUIPMENT LOCATED IN LABORATORY	EQUIPMENT FROM SUPPLY	CLASSIFIED MATERIAL	GRAPHIC AIDS AND UNCLASSIFIED MATERIAL
None	None	None	1. 3ABR53131-SG-302 2. TO 34W4-1-8 3. TO 34W4-1-5 4. Modern Welding (Chapter 6) 5. Chart CC74-114 Color Code Classification of Electrodes

CRITERION OBJECTIVES AND TEACHING STEPS

a. Given military specifications, select and identify the types of arc welding electrodes without error.

b. Given AWS numerical and color coded systems, select and identify the types of arc welding electrodes without error.

Teaching steps are listed in Part II.

ATC FORM AUG 72 770

GPO 1972 778-398/23

INTRODUCTION TIME: 10 Min

ATTENTION:

REVIEW: During our last lesson we learned the principles of operation and maintenance of arc welding machines. Evaluate outside assignment and critique missed items.

OVERVIEW: Upon completion of this lesson, students will learn the identification codes of metallic arc welding electrodes and be able to select proper electrodes for given welding operations.

MOTIVATION:

BODY TIME: 3 Hrs 40 Min

PRESENTATION
(Refer objectives # 1 & 2)

1. Types of coatings on electrodes and types of electrodes

   a. Designed with wire core and coated to allow for prevention of oxides and nitrides which cause brittleness in the weld

   b. Types of electodes

      (1) Bare-used with DC straight polarity when presence of slag is undesirable and removal of slag is not feasible

      (2) Light coated

      (3) Heavy coated

   c. Types of Coatings

      (1) Cellulose

         (a) Derived from wood pulp, sawdust, cotton or compositions of rayon

         (b) DC Reverse Polarity current

(c) Protects weld with slag

(2) Mineral

(a) Many different types such as potassium, natural silicates, as asbestos and clay

(b) Used with DC Straight Polarity

(c) Purpose is to protect the weld

(d) Burns at a lower temperature

2. Select and identify electrode types by:

a. Military specifications

(1) TO 34W4-1-5 and -8

(2) Air Force Supply Catalogs identify arc welding electrodes by Military Specification Numbers such as MIL-E15599

b. AWS Numerical and color code

(1) Four digit code
Example - E6013

(a) Letter (E) stands for electrodes

(b) First two digits (60) indicate PSI in thousands

(c) Third digit (1) indicates the recommended position, in this case, all positions

1 In special cases, it will identify the type of flux and polarity

(d) Fourth digit (3) indicates type of current or coating, in this case AC or DC Straight Polarity which is used with a mineral coating

(2) Five digit number code

(a) Is the same as the four digit code except that the first three digits indicate tensile strength in thousands of PSI

(b) Electrodes with the last digit of 5, 6, 7 or 8 are low hydrogen electrodes. Examples are E 7016 or E 347-16

(3) Color code

(a) Primary - Top tip of electrode

(b) Secondary - Spot or band on bare portion about 1/2" from top

(c) Group - just below the upper edge of coating

(d) Special - middle of the electrode a manufacturer's mark, not very common

3. Most common electrodes

a. E 6010

(1) No color marking

(2) All position

(3) DC Reverse Polarity

(4) Cellulose coating

(5) Best for vertical and overhead work

(a) Good penetration

(b) Fast Freeze effect

(c) Most used electrode

b. E 6011

(1) Blue secondary

(2) All position

(3) AC* or DCRP

(4) Designed as E 6010 except for use on AC

c. E 6012

(1) White secondary

(2) All position

(3) AC or DCSP

(4) Mineral coating

(5) Very good for poor fit-ups due to less penetration

(6) It is used primarily for carbon steels

d. E 6013

(1) Brown secondary

(2) All position

(3) AC* or DCSP

4. Rules for welding

a. Preparation and alignment

b. Correct electrode and current settings

c. Fill in craters

APPLICATION: #1. Students will be given military specifications as a reference to select, and identify the types of welding electrodes.

APPLICATION: #2. Given AWS numerical and color code systesm, select, and identify the different types of welding electrodes.

EVALUATION: Students will select and identify different types of welding electrodes, without error.

END OF DAY SUMMARY

1. Summary

   a. Types of coatings and electrodes

   b. Selection and identification of electrodes by means of

      (1) Military specifications

      (2) AWS code

      (3) Color code

   c. Most common electrodes

   d. Rules for welding

2. CTT Assignment

   a. Read 3ABR53131-SG-303

   b. Read MWHB Chpt 5 parn 11

INTRODUCTION TO NEW DAY'S INSTRUCTION

1. Evaluate CTT assignment, critique missed items.

2. Remotivation. Stress importance of knowing how to select and identify electrodes.

3. Review

   a. Types of coatings and electrodes

   b. Selection and identification of electrodes by means of

      (1) Military Specifications

      (2) AWS Code

      (3) Color code

   c. Most common electrodes

   d. Rules for welding

OVERVIEW: Using AWS numerical and color code systems, select and identify arc welding electrodes.

BODY

PRESENTATION (Cont.)

APPLICATION: Given AWS numerical and color code systems, select and identify the different types of welding electrodes.

EVALUATION: Students will select and identify different types of welding electrodes, without error.

CONCLUSION TIME: 10 Min

1. Summary
   a. Types of electrodes and coatings
   b. Selection of electrodes by means of
      (1) Military Specifications
      (2) AWS Codes
      (3) Color code
   c. Most common electrodes
   d. Rules for welding
2. Assignment. Assignment given in end of day summary.

LESSON PLAN (Part I, General)

APPROVAL OFFICE AND DATE	INSTRUCTOR
TWSTI 27 Sept 75 Ltr Ltr	
COURSE NUMBER	**COURSE TITLE**
3ABR53131	Metals Processing Specialist
BLOCK NUMBER	**BLOCK TITLE**
III	Introduction to Metallic Arc Welding

LESSON TITLE
Stringer Beads and Building up Worn Surfaces

LESSON DURATION

CLASSROOM/Laboratory	Complementary	TOTAL
D & D 1 hr/ Perf 5 hrs	2 hrs	8 hrs

POI REFERENCE

PAGE NUMBER	PAGE DATE	PARAGRAPH
23	23 Sep 1975	3

STS/CTS REFERENCE

NUMBER	DATE
STS 531X1	31 May 1975

SUPERVISOR APPROVAL

SIGNATURE	DATE	SIGNATURE	DATE

PRECLASS PREPARATION

EQUIPMENT LOCATED IN LABORATORY	EQUIPMENT FROM SUPPLY	CLASSIFIED MATERIAL	GRAPHIC AIDS AND UNCLASSIFIED MATERIAL
1. Arc Welding Booth Complete	Consolidated Toolkit	None	1. 3ABR53131-SG-303 2. TO 34W4-1-5 3. Modern Welding (Chapter 5) 4. Film: FLC-1-0126 Fundamentals of Arc Welding

CRITERION OBJECTIVES AND TEACHING STEPS

a. Given metallic arc welding equipment and carbon steel specimens, set up and employ proper welding techniques in building up flat and worn surfaces, free of undercut, overlap, and slag inclusions for a total combined distance of no less than 3/4 of the length of the specimen, excluding the first 1/2 inch start and the last 1/2 inch finish. All shop safety, good housekeeping, and fire prevention measures must be observed.

Teaching steps are listed in Part II.

ATC FORM AUG 72 770

☆ GPO: 1972 778-388/23

INTRODUCTION TIME: 10 Min.

1. Attention:

2. Review: During your last lesson you learned the identification and selection of metallic arc welding electrodes.

3. Overview: Upon completion of this lesson, students will run stringer beads in building up worn surface material.

4. Motivation:

BODY TIME: 5 Hrs 40 Min

PRESENTATION
(Refer Obj. 3a)

1. Employ proper welding techniques in building up flat surfaces

   a. Padding--building up a worn surface or increasing the thickness of the part.

   b. Metal preparation; cleaning the surface by:

      1. Mechanical Methods

         a. Wire brushing or buffing for dirty, rusty or scaly parts--dirt, rust and scale cause hard spots and results in a weaker weld.

      2. Chemical Methods

         a. Trichlorethylene in vapor degreaser for oily or greasy parts--welding on oily or greasy metal causes a porous weld.

   c. Procedures for Padding

      (1) Electrode is held so it will "bite" into parent metal and into ½ of the adjacent bead in order to avoid slag inclusions.

      (2) Run beads parallel or right angle, longest dimensions first.

(a) Longest period of time between concentrations of heat

(b) Minimize stresses

(c) Allows time for the work to absorb and distribute heat

(3) Encircle the part with a perimeter bead.

(a) Stringer beads are more easily ended

(b) Possibility of crater cracks is reduced

(c) Controls distortion

2. Practice shop safety in performance of required tasks

a. Use proper gloves for handling metal

b. Use pliers for hot metal

c. Check machine for

(1) Cables with bare wire

(2) Wear on electrode holder

d. Keep work area clean

3. Utilize health and safety equipment

a. Wear gloves, apron, and jacket for protection from the arc rays and globules of hot molten metal

b. Helmet

(1) Correct lens number

(2) Clear lens for chipping

c. Grinding

(1) Use face shield

(2) Remove jewelry

(3) Check grinder wheels and tool rest. If wheel needs dressing or tool rest needs adjusting, notify instructor for correction.

(4) Pay attention to what you are doing.

APPLICATION:

1. Students will pad metal plates using stringer beads.

2. Students will observe all safety rules during accomplishment of project.

3. Assistance will be given as needed.

EVALUATION:

1. Students will be checked for proper welding procedure, observance of safety, good housekeeping and fire prevention measures. Assistance will be given as needed.

END OF DAY SUMMARY

SUMMARY

1. Techniques in padding
2. Practice of shop safety
3. Utilization of health and safety equipment
4. Grinding

CTT ASSIGNMENT:

1. Read 3ABR53230-SG-304 and answer questions. POI Item 3a
2. Study Modern Welding Handbook (Chapter 5)

(Day 3, 1 hr) INTRODUCTION TO NEW DAY'S INSTRUCTION

1. Evaluate CTT Assignment and Critique missed items.

2. Remotivation:

3. Review:

   a. Techniques in padding

   b. Practice of shop safety

   c. Utilization of health and safety equipment

   d. Grinding

4. Overview: Students will run stringer beads in building up worn surfaces materials.

PRESENTATION (continued)
(Refer Objective 3a)

APPLICATION

1. Students will continue on padding plate.

2. Students will observe all safety precautions

EVALUATION

1. Students will complete and turn in to their instructor their padded plates which must meet criteria covered in this lesson. Assistance will be given as needed.

CONCLUSION TIME: 10 Min

1. Summary

   a. Techniques in padding

   b. Practices of shop safety

   c. Utilization of health and safety equipment

   d. Grinding

2. Assignment

Given at End of Day Summary.

LESSON PLAN (Part I, General)

APPROVAL OFFICE AND DATE: TWSTI	INSTRUCTOR:
COURSE NUMBER: 3ABR53131	COURSE TITLE: Metals Processing Specialist
BLOCK NUMBER: III	BLOCK TITLE: Introduction to Metallic Arc Welding
LESSON TITLE: Fillet Welds in the Flat and Horizontal Position	

LESSON DURATION

CLASSROOM/Laboratory	Complementary	TOTAL
D & D 3 hrs/Perf 11 hrs	4 hrs	18 hrs

POI REFERENCE

PAGE NUMBER	PAGE DATE	PARAGRAPH
24	23 Sep 1975	4

STS/CTS REFERENCE

NUMBER	DATE
STS 531X1	31 May 1975

SUPERVISOR APPROVAL

SIGNATURE	DATE	SIGNATURE	DATE

PRECLASS PREPARATION

EQUIPMENT LOCATED IN LABORATORY	EQUIPMENT FROM SUPPLY	CLASSIFIED MATERIAL	GRAPHIC AIDS AND UNCLASSIFIED MATERIAL
Arc Welding Booth Complete	Consolidated Toolkit	None	1. 3ABR53131-SG-304 2. TO 34W4-1-5 3. Modern Welding (Chapter 5)

CRITERION OBJECTIVES AND TEACHING STEPS

a. Given metallic arc welding equipment and carbon steel sheet specimens, set up and make fillet welds in the flat position, free of excessive penetration, overlap, undercut, and slag inclusions for a total combined distance of no less than 3/4 of the length of the specimen excluding the first 1/2 inch start and the last 1/2 inch finish. All shop safety, good housekeeping, and fire prevention measures must be observed.

b. Given metallic arc welding equipment and carbon steel sheet specimens, set up and make fillet welds in the horizontal position, free of excessive penetration, overlap, undercut, and slag inclusions for a total combined distance of no less than 3/4 of the length of the specimen, excluding the first 1/2 inch start and the last 1/2 inch finish. All shop safety, good housekeeping and fire prevention measures must be observed.

Teaching steps are listed in Part II.

INTRODUCTION TIME: 10 Min

1. Attention:

2. Review: During our last lesson we learned to run stringer beads in building up worn surface material.

3. Overview: Upon completion of this discussion students will set up and make fillet welds in the flat and horizontal positions.

4. Motivation:

BODY TIME: 13 hrs, 40 Min

PRESENTATION:
(Refer Objectives 4a & b)

1. Students will discuss and learn the principles and necessary steps involved in setting up and welding fillet welds of carbon steels in the flat position.

   a. Types of fillet joints

      (1) Lap joint - used where joint surfaces are not required to be flat, or on the same plane.

         (a) Single lap

            1 Stresses will occur at the edges of the weld under fatigue or impact loads.

            2 Plates will pull out of line under tension.

         (b) Double Lap

            1 Good for sheer and tension

            2 Unsuitable under fatigue or impact loads

(2) Tee Joint

(a) One plate is perpendicular to the face of another plate

(b) Very rigid for structural work

(c) May be welded from either side

b. Set up the weld tee joint in the flat position

(1) Inclined from 0° to 15°

(2) Rotation of face is 150° to 210°

c. Welding procedure

(1) For lap joints

(a) Metal to overlap 3-4T

(b) Electrode angle 15° to 30° from vertical

(c) Direct arc to penetrate both plates

(2) For Tee Joints

(a) Can be welded in any position

(b) No bevel on metal up to 3/16" thickness

(c) Single bevel on 3/16" to 3/8" metal thickness with 1/16" shoulder. Spacing to be 1/16".

(d) Double bevel metal of over 3/8" thickness, with 1/16" shoulder. Spacing is 1/16".

d. Weld Specifications

(1) For Lap Joints

(a) Upper leg 1T

(b) Lower leg 1½T

(c) Throat 1T

(2) For Tee Joint

(a) Upper leg 1½T

(b) Lower leg 1½T

(c) Throat 1T

APPLICATION:

1. Students will set up and weld tee joints in the flat position using stringer beads for each successive pass, and as outlined in SG-304.

2. All rules of safety, good housekeeping and fire prevention will be observed.

3. Assistance will be given as necessary.

EVALUATION:

Students will be checked for proper welding procedure.

END OF DAY SUMMARY

Summary:

1. Types of fillet joints

2. Tee joint in flat position

3. Welding procedure

4. Weld specifications

CTT Assignment:

1. Review 3ABR53230-SG-304

2. Modern Welding Handbook
Chapter 5

(Day 4, 6 hrs) INTRODUCTION TO NEW DAY'S INSTRUCTION

1. Evaluate CTT Assignment

2. Remotivation

3. Review:

   (a) Types of fillet joints

   (b) Tee joint in flat position

   (c) Welding procedure

   (d) Weld specifications

4. Overview: Upon completion of the lesson students will set up, and make fillet welds in the flat and horizontal position.

PRESENTATION (Continued)

2. Students will discuss and learn the principles and techniques of setting up and welding fillet welds of carbon steel in the horizontal position.

   (a) Parts are inclined 45° or more with the weld running horizontally.

   (b) Use multiple passes as necessary.

   (c) Use stringer beads, building from bottom plate to top plate.

   (d) Electrode held perpendicular to line of weld, bisecting angle between two joint edges.

      (1) Tilted upward

      (2) Directed back toward weld crater to assist in washing slag back, and filling undercut.

APPLICATION

1. Students will continue to weld tee fillet joints in the flat position, while observing all rules of safety, good housekeeping and fire prevention.

2. Students will set up and weld tee joints in the horizontal position, using stringer beads for each pass, and as outlined in SG-304.

3. Assistance will be given as needed.

EVALUATION

1. Students will be checked for proper welding procedure.

2. Each student will complete and turn in their fillet welds, which will meet all criterion and specifications outlined in this lesson.

END OF DAY SUMMARY

Summary:

1. Incline parts at more than 45° angle, weld running horizontally.

2. Stringer beads, multiple passes.

3. Angle and tilt of electrode

CTT Assignment:

1. Read 3ABR53230-SG-305 and answer questions.

2. Modern Welding Handbook Chapter 5.

(Day 5, 3 hr) INTRODUCTION TO NEW DAY'S INSTRUCTION

1. Remotivation

2. Review

   (a) Incline parts at more than 45° angle, weld running horizontal.

   (b) Stringer beads, multiple passes

   (c) Angle and tilt of electrode

3. Overview: Upon completion of the lesson, students will set up and make fillet welds in the horizontal position.

PRESENTATION (Continued)
(Ref Objective 4b)

APPLICATION:

1. Students will continue to weld tee fillet joints in the horizontal position, while observing all rules of safety, good housekeeping and fire prevention.

2. Assistance will be given as needed.

Training equipment to be used at this time include:

a. arc welding booth complete
b. tool kit

EVALUATION:

1. Students will be checked for proper welding procedure.

2. Each student will complete and turn in their fillet welds, which will meet all criterion and specifications outlined in this lesson.

3. Students will be given a series of questions of which 75% accuracy of response is required.

CONCLUSION TIME: 10 Min

1. Summary:

   (a) Types of fillet joints

   (b) Welding Tee Joints

      (1) in flat position

      (2) in horizontal position

   (c) Welding procedures

   (d) Weld specifications

2. Assignment:

   Given at End of Day Summary.

REMOTIVATION:

CLOSURE:

LESSON PLAN (Part I, General) 46

APPROVAL OFFICE AND DATE	INSTRUCTOR
TWSTI 22 Jan 75 Ltr Sgn Rel	
COURSE NUMBER 3ABR53131	**COURSE TITLE** Metals Processing Specialist
BLOCK NUMBER III	**BLOCK TITLE** Introduction to Metallic Arc Welding

LESSON TITLE
Butt Joints of Carbon Steel Plate

LESSON DURATION

CLASSROOM/Laboratory	Complementary	TOTAL
D & D 1 hr/Perf 14 hrs	6 hrs	21 hrs

POI REFERENCE

PAGE NUMBER	PAGE DATE	PARAGRAPH
25	23 Sep 1975	5

STS/CTS REFERENCE

NUMBER	DATE
STS 531X1	31 May 1975

SUPERVISOR APPROVAL

SIGNATURE	DATE	SIGNATURE	DATE

PRECLASS PREPARATION

EQUIPMENT LOCATED IN LABORATORY	EQUIPMENT FROM SUPPLY	CLASSIFIED MATERIAL	GRAPHIC AIDS AND UNCLASSIFIED MATERIAL
1. Arc Welding Booth Complete 2. Grinders 3. Tensile Tester 4. Power Shears 5. Trainer 3218 Electric (WELded Joints)	Consolidated Toolkit	None	1. 3ABR53131-SG-305 2. TO 34W4-1-5 3. Modern Welding (Chapter 5) 4. Film: FLC 16/203 Prevention and Control of Manual Arc Welding

CRITERION OBJECTIVES AND TEACHING STEPS

a. Given power shears, grinding equipment, and metal specimens, set up and prepare joints for welding IAW TO 34W4-1-5. All shop safety, good housekeeping, and fire prevention measures must be observed.

b. Using a list of statements, select weld specification limits pertaining to welding plate with 75% accuracy.

c. Given metallic arc welding equipment and carbon steel plate specimens, set up and weld butt joints in the flat position with 100% penetration, free of undercut, overlap, and slag inclusions, for a total combined distance of no less than 3/4 of the length of the specimen excluding the first 1/2 inch start and the last 1/2 inch finish. All shop safety, good housekeeping, and fire prevention measures must be observed.

Teaching steps are listed in Part II.

INTRODUCTION TIME: 10 Min.

1. Attention:

2. Review: During our last lesson we learned and applied techniques used to weld fillet joints in the flat and horizontal positions.

3. Overview: Upon completion of this lesson, students will learn and apply welding techniques in making butt welds on steel plate.

4. Motivation:

BODY TIME: 14 Hrs, 40 Min.

PRESENTATION:

Reference Objectives 5a, b, and c

1. Preparation of Joints for Welding

   a. Types of joints for butt joints of steel plate

      (1) Double bevel

      (2) Double vee

      (3) Single and double U

   b. Double Bevel

      (1) Metals over 3/8" T

      (2) Bevel angle 30° to 35°

      (3) Used when the joining plate cannot be beveled

   c. Double V

      (1) Differs from double bevel in that both plates are beveled

      (2) Included angle is 60° to 75°

      (3) Used on metal over 3/8" T

d. Generally butt joints are welded on both sides.

(1) Easier welded

(2) Less distortion

(3) Insure better weld metal in heavy sections.

e. The single and double U

(1) Single U

(a) Used in place of double V

(b) Used on metal 1/2" to 3/4" T

(c) More satisfactory and requires less filler metal than V bevels for heavy sections and deep grooves.

(d) Weld is made on one side, except last bead which is made on opposite side.

(2) Double U

(a) Used on heavy plate over 3/4" T

(b) Requires less filler rod than single U

(c) Welded on both sides

(d) Grooves are made with a cutting torch, or they may be machined.

2. Weld Specifications

Use Trainer 3218, Electric Weld

a. Bead width to be approx. 1/8" wider than original bevel - 1 to 2 X T.

b. Depth of fusion is 1/16" min.

c. Reinforcement height 1/8", or 25% of T.

d. Penetration - 100%

3. Weld butt joint in flat position to study guide specifications

   a. Prepare joint to specified bevel as previously outlined.

   b. Space plates at a distance about the width of the flat shoulder at bottom of joint edge.

   c. Tack weld and check alignment.

   d. Insure penetration at root of weld.

   e. Use stringer beads for filling up.

4. Shop Safety

   a. Remove all jewelry before operating any shop equipment

   b. Use gloves when handling metal with sharp edges

   c. Use pliers for handling hot metal

   d. Use faceshield when grinding. Do not use arc helmet when grinding.

   e. Check lens in hood for cracks.

   f. Wear protective clothing when arc welding.

Show FLC/203, Prevention and Control of Manual Arc Welding

Application:

#1 Students will set up and prepare butt joints for welding.

#2 Instructor will administer appraisal test, on weld specifications pertaining to welding.

#3 Upon completion of lesson students will set up and weld butt joints in the flat position.

Evaluation:

#1 Instructor will check for compliance with TO 34W4-1-5.

#2 Instructor will check to make sure that students have answered questions with 75% accuracy.

a. What is the reinforcement of a 3/16" butt joint?

* 25% of T (Fig 37; pg 42)

b. What is the required penetration of a ½" butt joint?

* 100% (Fig 37; pg 42)

c. What size electrode is used for the root pass on a ½" butt joint?

* 1/8" or 5/32" diameter (pg 40)

d. Why is a long arc held at the start of a butt joint of light or heavy thickness?

* To obtain good penetration at the start of the weld. (pg 41)

e. What is the reinforcement width of a butt joint on ½" plate?

* 2 to 3 X T (Fig 37; pg 42)

f. What is the depth of fusion in a ½" butt joint?

* Minimum of 1/16" (pg 42)

g. What must be done after tack welding a butt joint?

* Check alignment (pg 43)

h. What is the angle of bevel on the one plate of a single bevel?

* 30 to 35 degrees (pg 38)

#3 Instructor will check progress, and make sure that students have welded butt joints in the flat position IAW POI objective 5c.

END OF DAY SUMMARY

Summary:

1. Types of butt joints
   a. Double bevel
   b. Double vee
   c. Double U
2. Weld specifications
3. Welding procedure

CTT Assignment:

1. Review 3ABR53131-SG-305
2. Review Chap 5 of MWHB

(Day 6, 6 Hrs) INTRODUCTION TO NEW DAY'S INSTRUCTION

1. Evaluate CTT assignment and critique missed items.
2. Remotivation:
3. Review:
   a. Types of butt joints for steel plate
      (1) Double bevel
      (2) Double vee
      (3) Double U
   b. Weld specifications
   c. Welding procedure
4. Overview: Upon completion of the lesson students will set up, and weld butt joints in the flat position.

PRESENTATION (Continued)

Reference objectives (5c)

APPLICATION:

1. Students will set up, and weld heavy steel plate butt joints in the flat position.

EVALUATION: Instructor will check the progress of the student. Instructor will also insure that the student's welds are IAW POI item 5c.

END OF DAY SUMMARY

Summary:

1. Types of butt joints
   a. Double bevel
   b. Double vee
   c. Double U
2. Weld specifications
3. Welding procedure

CTT Assignment:

1. Read 3ABR53131-SG-306
2. Read MWHB Chap 5

(Day 7, 6 Hrs) INTRODUCTION TO NEW DAY'S INSTRUCTION

1. Evaluate CTT assignment and critique missed items.
2. Remotivation:
3. Review
   a. Types of butt joints for steel plate
      (1) Double bevel
      (2) Double vee
      (3) Double U
   b. Welding specifications
   c. Welding procedure
4. Overview: Upon completion of the lesson students will set up, and weld heavy carbon steel butt joints.

PRESENTATION (Continued)

Refer objectives (5c)

APPLICATION:

1. Students will set up and weld butt joints of steel plate in accordance with all welding specifications, procedures and rules of safety covered in this lesson.

EVALUATION:

1. Students will complete and turn in welded butt joints which must meet all standards covered in POI objective 5c.

CONCLUSION TIME: 10 Min.

1. Summary

   a. Types of butt joints

      (1) Double bevel

      (2) Double vee

      (3) Double U

   b. Weld specifications

   c. Welding procedure

2. CTT Assignment

   a. Read 3ABR53131-SG-306

      and answer questions

   b. Read MWHB Chap 5.

LESSON PLAN (Part I, General)

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APPROVAL OFFICE AND DATE	INSTRUCTOR
TWSTI 25 Jan 1976	
COURSE NUMBER	COURSE TITLE
3ABR53131	Metals Processing Specialist
BLOCK NUMBER	BLOCK TITLE
III	Introduction to Metallic Arc Welding

LESSON TITLE: Butt Joints of Carbon Steel Sheet

LESSON DURATION		
CLASSROOM/Laboratory	Complementary	TOTAL
D & D 2 hrs/Perf 14 hrs	2 hrs	18 hrs

POI REFERENCE		
PAGE NUMBER	PAGE DATE	PARAGRAPH
26	23 Sep 1975	6

STS-CTS REFERENCE	
NUMBER	DATE
STS 531X1	31 May 1975

SUPERVISOR APPROVAL			
SIGNATURE	DATE	SIGNATURE	DATE

PRECLASS PREPARATION

EQUIPMENT LOCATED IN LABORATORY	EQUIPMENT FROM SUPPLY	CLASSIFIED MATERIAL	GRAPHIC AIDS AND UNCLASSIFIED MATERIAL
1. Arc Welding Booth Complete 2. Grinders 3. Power Shears 4. Trainer 3218	Consolidated Toolkit	None	1. 3ABR53131-SG-306 2. TO 34W4-1-5 3. Modern Welding (Chapter 5) 4. Slides - Butt Joints S71-2533 - S81-2704

CRITERION OBJECTIVES AND TEACHING STEPS

a. Given metallic arc welding equipment and light gauge carbon steel sheet specimens, set up and weld butt joints in the flat position, with 100% penetration, free of undercut, overlap, and slag inclusions for a total combined distance of no less than 3/4 of the length of the specimen, excluding the first 1/2 inch start and the last 1/2 inch finish. All shop safety, good housekeeping, and fire prevention measures must be observed.

b. Given metallic arc welding equipment and heavy carbon steel sheet specimens, set up and weld butt joints in the flat position, with 100% penetration, free of undercut, overlap, and slag inclusions for a total combined distance of no less than 3/4 of the length of the specimen, excluding the first 1/2 inch start and the last 1/2 finish. All shop safety, good housekeeping, and fire prevention measures must be observed.

Teaching steps are listed in Part II.

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INTRODUCTION TIME: 10 Min.

Attention:

Review: During our last lesson we learned to apply techniques used to weld butt joints of steel plate. Evaluate CTT assignment and critique missed items.

Overview: Upon your completion of this lesson, students will set up and weld butt joints of steel sheet.

Motivation:

BODY TIME: 15 hrs. 40 Min.

Presentation:
(Refer objective)

1. Preparation of joints for welding:

   a. Types of joints for sheet

      (1) Single bevel

      (2) Single vee

      (3) Square edge

   b. Square edge

      (1) No bevel required

      (2) Used on metal 1/8" or less

      (3) Burrs should be removed

   c. Single bevel

      (1) Metal 1/8" to 3/8"

      (2) Bevel both plates to an included angle of 60° to 75°

2. Weld Specifications: Use Trainer 3218; Electric Weld

   a. Width is 2 to 3 XT

   b. Bead reinforcement is 25% of T

   c. Penetration is 100%

3. Weld butt joints to study guide specifications, using following procedure to insure good weld beads.

   a. Prepare joint as outlined previously

   b. Tack weld, then check alignment

   c. Insure penetration is 100%

4. Shop Safety

   a. Use all protective clothing and equipment

   b. Operate machine only that you have been checked out on

   c. Check equipment before using

Application:

1. Students will set up and weld light gauge sheet steel butt joints in the flat position.

Evaluation:

1. Students will be given a series of questions concerning weld specifications and welding procedures of steel sheet butt joints. Minimum of 75% correct response is required.

2. The instructor will check welds made on light sheet steel to ensure they have been made to standards set forth by the Criterion Checklist.

END OF DAY SUMMARY TIME: 10 Min.

1. Summary:

   a. Preparation of joints for welding

   b. Weld specifications

   c. Welding procedure

   d. Shop safety

2. Assignment:

   a. Review 3ABR53131-SG-306

   b. Review MWH, Chapter 5

   c.

   d.

INTRODUCTION TO NEW DAY'S INSTRUCTION Day 9, 6 Hrs

1. Evaluate assignment and critique missed items.

2. Remotivation:

3. Review:

   a. Preparation of joints for welding

   b. Weld specifications

   c. Welding procedure

   d. Shop safety

4. Overview: Upon completion of the lesson, students will set up and weld butt joints of light carbon steel sheet.

Presentation: Cont'd
(Refer objective 6b)

Application:

1. Students will set up and weld butt joints of heavy carbon steel plate.

Evaluation:

1. Students will be given a series of questions concerning weld specifications and welding procedures of steel sheet butt joints. Minimum of 75% correct response is required.

2. Instructor will observe students welding heavy carbon steel sheet butt joints, and ensure that they are IAW the Criterion Checklist.

END OF DAY SUMMARY

1. Summary:

   a. Preparation of joints for welding

   b. Weld specifications

   c. Shop safety

2. Assignment:

   a. Review 3ABR53131-SG-306

   b. Read MWHB, Chapter 5

   c. Review for block test

INTRODUCTION TO NEW DAY'S INSTRUCTION Day 10, 4 Hrs

1. Evaluate assignment and critique missed items

2. Remotivation:

3. Review:

   a. Preparation of joints for welding

   b. Weld specifications

   c. Welding procedure

   d. Shop safety

4. Overview: Upon completing the lesson, students will set up and weld heavy carbon steel sheet butt joints in the flat position.

Presentation: Cont'd.
(Refer objective 6b)

Application: Students will continue to set up and weld butt joints of heavy carbon steel plate in the flat position.

Evaluation: Instructor will check students' welds on heavy carbon steel butt joints for proper specifications IAW Criterion Checklist.

CONCLUSION: TIME: 10 Min.

1. Summary:

   a. Preparation of joints for welding

   b. Weld specifications

   c. Welding procedures

   d. Shop safety

2. Assignment:

   a. Read 3ABR53131-SG-401 and answer questions

   b. Read MWHB, Chapter 5

   c.

   d.

Remotivation:

Closure:

LESSON PLAN (Part I, General)

APPROVAL OFFICE AND DATE	INSTRUCTOR
TWSTI 8 Oct 75	
COURSE NUMBER	**COURSE TITLE**
3ABR53131	Metals Processing Specialist
BLOCK NUMBER	**BLOCK TITLE**
IV	Special Metallic Arc and Resistance Welding Applications

LESSON TITLE
Fillet Welds in the Vertical Position

LESSON DURATION

CLASSROOM/Laboratory	Complementary	TOTAL
D & D 1 hr/Perf 11 hrs	2 hrs	14 hrs

POI REFERENCE

PAGE NUMBER	PAGE DATE	PARAGRAPH
27	23 Sep 1975	1

STS/CTS REFERENCE

NUMBER	DATE
STS 531X1	31 May 1975

SUPERVISOR APPROVAL

SIGNATURE	DATE	SIGNATURE	DATE

PRECLASS PREPARATION

EQUIPMENT LOCATED IN LABORATORY	EQUIPMENT FROM SUPPLY	CLASSIFIED MATERIAL	GRAPHIC AIDS AND UNCLASSIFIED MATERIAL
1. Arc Welding Booth Complete 2. Power Shears 3. Trainer: 3218 Electrical Weld ARC Welded Joints	Consolidated Toolkit	None	1. 3ABR53131-SG-401 2. TO 31W4-1-5 3. Modern Welding (Chapter 5)

CRITERION OBJECTIVES AND TEACHING STEPS

a. Given metallic arc welding equipment and carbon steel plate specimens, set up and make fillet welds in the vertical position, free of undercut, overlap, and slag inclusions for a total combined distance of no less than 3/4 of the length of the specimen, excluding the first 1/2 inch start and the last 1/2 inch finish. All shop safety, good housekeeping, and fire prevention measures must be observed.

Teaching steps are listed in Part II.

GPO 1972 779-399/23

INTRODUCTION

Time: 10 min

1. ATTENTION:

2. REVIEW: Previous block covered: Operation of machines, polarity of electricity, selection of electrode. Evaluate CTT assignment and critique missed items.

3. OVERVIEW: Upon completion of this lesson, students will be able to make fillet welds in the vertical position to study guide specifications.

4. MOTIVATION:

BODY

Time: 11 hrs 40 min

PRESENTATION
Refer to objective #1a

1. Vertical position welding

   a. More difficult than flat or horizontal welding

      (1) slower speed of travel

   b. Overcome force of gravity by

      (1) hold short arc

      (2) manipulate electrode

      (3) control molten pool

         (a) size of molten pool 2-3T

      (4) Gas expansion

         (a) strongest force of metal transfer

            1 Caused by burning of electrode coating

2. Electrode and current

   a. E6010 highly recommended for position welding - all positions

b. Electrode coating

(1) Heavy

(2) Light

c. Reverse Polarity

(1) Heat on electrode tip

(a) Positive side welding circuit

(2) Aids to secure proper penetration

(a) Positive side welding circuit

d. Smaller diameter electrode

(1) Less current

(2) Aid in controlling molten pool

(3) Over come gravity, surface tension of the electrodes

(4) Maximum practical size 3/16"

3. Welding technique

a. Electrode angle 75° down for starting shelf

b. Electrode angle for continuing bend 15° up

(1) Welding sequence

(a) Hold short arc when depositing metal

(b) Arc never broken

(c) Build shelf

(d) Deposit another bead after shelf solidifies

4. Wider Beads

a. More current

b. Larger electrode - 3/16"

c. Weaving motion

(1) Side to side motion and slightly outward

(a) To eliminate a highly crown bead

(2) Pause at side to fill undercut and prevent overlap

(a) Allows pool to solidify

(b) Eliminates high beads

5. Fillet welds on tee joints

a. Number of beads will depend on thickness of metal

(1) The thicker the metal the more pauses required

b. Series of stringer beads

(1) Always stringer bead in root of joint

(a) For penetration

c. Always knock off slag prior to depositing next bead

(1) Prevent slag inclusions

6. Practice shop safety in performance of required tasks

a. No horse play

b. No smoking

c. Maintain clean area and clean daily

d. Inspect cables

(1) Cracks

(2) Frayed wires

. Utilize health and safety equipment

a. Welding helmet and eye protection

(1) Check Jally

(a) For cracked lens

(b) For proper shade - #10

b. Gloves

c. Clothing suitable for job

(1) High top boots

(2) Long sleeved shirts

(3) Aprons

(4) Leathers

d. Use guards on machinery

(1) Face shields

APPLICATION:

1. Students will weld fillet welds in the vertical position to specifications of T034W4-1-5

2. Students will observe all safety precautions during accomplishment of projects

VALUATION:

1. Students projects will be checked during welding process for proper procedure and preparation of material. Assistance will be given when necessary.

END OF DAY SUMMARY

SUMMARY:

1. Vertical position welding
2. Electrode and current
3. Welding techniques
4. Width beads
5. Fillet welds
6. Shop safety
7. Safety equipment (personal)

CTT Assignment
POI Item 1a

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following assignment. After completion of assignment will be required to answer questions with 75% accuracy.

1. Review 3ABR52131-SC-401.
2. Review TO 34W-1-5 (chap 7)
3. Modern Welding (chap 5 pages 5-21-22)

INTRODUCTION TO NEW DAY'S INSTRUCTION

Refer to Objective 1a

1. Evaluate - CTT assignment critique missed items.
2. Remotivation
3. Review:
   a. Vertical position welding
   b. Electrode and current
   c. Welding techniques
   d. Width of bead
   e. Fillet Welds
   f. Shop Safety
   g. Safety Equip[illegible]ersonal)
4. Overview:
   a. Fillet weld[illegible]rtical position

APPLICATION: Cont'd

1. Student will cont[illegible]ld fillets in the vertical p[illegible]
2. Students will observe pre-cautions during ac[illegible] projects.

EVALUATION:

1. Student projects will be [illegible]ng welding process for proje[illegible]. Assistance will be given [illegible]ts.
2. Instructor will check stu[illegible]

CONCLUSION Time: 10 min

1. Summary

   a. Fillet welds in vertical position

   b. Welding technique

   c. Safety practices

DAY 2

2. CTT Assignment: Students will read/review following assignment; after assignment, will answer questions with 75% accuracy. Read 3ABR53131-SG-402 (POI Item, POI Time 2 hrs).

3. Remotivation:

4. Closing Statement:

LESSON PLAN (Part I, General)

APPROVAL OFFICE AND DATE, TWSTI [illegible]	INSTRUCTOR
COURSE NUMBER 3ABR53131	COURSE TITLE Metals Processing Specialist
BLOCK NUMBER IV	BLOCK TITLE Special Metallic Arc and Resistance Welding Applications

LESSON TITLE
Fillet Welds in the Overhead Position

LESSON DURATION

CLASSROOM/Laboratory	Complementary	TOTAL
D & D 1 hr/Perf 17 hrs	6 hrs	hrs

POI REFERENCE

PAGE NUMBER	PAGE DATE	PARAGRAPH
28	23 Sep 1975	2

STS-CTS REFERENCE

NUMBER	DATE
STS 531X1	31 May 1975

SUPERVISOR APPROVAL

SIGNATURE	DATE	SIGNATURE	DATE

PRECLASS PREPARATION

EQUIPMENT LOCATED IN LABORATORY	EQUIPMENT FROM SUPPLY	CLASSIFIED MATERIAL	GRAPHIC AIDS AND UNCLASSIFIED MATERIAL
1. Arc Welding Booth Complete 2. Power Shears 3. Trainer: 3218 Electric ARC WELDED JOINTS	Consolidated Toolkit	None	1. 3ABR53131-SG-402 2. TO 31W1-1-5 3. Modern Welding (Chapter 5)

CRITERION OBJECTIVES AND TEACHING STEPS

a. Given metallic arc welding equipment and carbon steel plate specimens, set up and make fillet welds in the overhead position, free of undercut, overlap and slag inclusions for a total combined distance of no less than 3/4 of the specimen, excluding the first 1/2 inch start and the last 1/2 inch finish. All shop safety, good housekeeping, and fire prevention measures must be observed.

Teaching steps are listed in Part II.

INTRODUCTION Time: 10 min

1. Attention:

2. Review: Previous lesson covered vertical welding, electrodes, manipulation, angle and current settings. Evaluate CTT assignment. Critique missed items.

3. Overview: Upon completion of this lesson students will be able to make fillet welds in the overhead position to study guide specifications.

4. Motivation:

BODY Time: 17 hrs 40 min

PRESENTATION
Refer to Objective #2a

1. Overhead welding

   a. Used in erection of structures

   b. Probably hardest position

      (1) Falling metal

      (2) Uncomfortable

   c. Forces in arc

      (1) Most effective-gas expansion

      (2) Biggest aid in overhead welding

2. Weld metal transfer

   a. Short arc

      (1) To control molten pool

   b. Electrode angle

      (1) 20° to Vertical Plate

      (2) 15° Direction of weld

c. Forces that aid in metal transfer

(1) Adhesion

(2) Surface tension of base metal

d. Forces that hinder metal transfer

(1) Gravity

(2) Surface tension of electrode

(3) Cohesion

e. Pre-heat heavy joints

(1) Hold long arc momentarily

3. Electrodes and current

a. Electrodes designed for overhead

(1) 6010 - Ex.

(2) 3/16 max. practical size

b. DC Reverse current

(1) Heat on electrode tip

(2) Positive side of circuit

(3) Aids in securing penetration

c. Amount of current

(1) Depends on diameter of electrode

(2) Thickness of material

4. Welding Technique

a. Hold short arc

b. Series of stringer beads

(1) Smaller than flat

(2) First Pass-for penetration

c. Penetration

(1) Indicated by Depth of crater

d. Remove slag and oxides

(1) To prevent slag inclusions

(2) Before making additional beads

(3) Chipping hammer and wire brush

5. Practice shop safety in performance of required tasks

a. No horse play

b. No smoking

c. Maintain clean area and clean daily

d. Inspect cables

(1) Cracks

(2) Frayed wires

6. Utilize health and safety equipment

a. Welding helmets and eye equipment

(1) Check daily

(a) For cracked lens

(b) For proper shade #10

b. Gloves

c. Clothing suitable for job

(1) High top boots

(2) Long sleeved shirts

(3) Aprons

(4) Leathers

d. Use guards on machinery

(1) Face shields

APPLICATION:

1. Students will weld fillet welds in the overhead position to TO 34W4-1-5 specifications.

2. Students will observe all safety precautions during accomplishment of projects.

VALUATION:

1. Students projects will be checked during welding process for proper preparation and procedures. Assistance will be given when necessary.

END OF DAY SUMMARY

SUMMARY:

1. Overhead welding
2. Weld metal transfer
3. Electrodes and current
4. Welding technique
5. Practice shop safety
6. Safety equipment (personal)

ASSIGNMENT:

DAY 3

CTT assignment given at End of Day Summary

1. Review:

   3ABR53/3/ SG-402

2. Review:

   TO 34W4-1-5

3. Modern Welding Handbook (Chapter 5,)

INTRODUCTION TO NEW DAYS INSTRUCTION

Refer to Objective 2a

REMOTIVATION:

Review:

a. Overhead position welding

b. Weld metal transfer

c. Electrodes and current

d. Welding technique

e. Shop safety

f. Safety equipment (personal)

Overview - Fillet welds in Overhead Position

APPLICATION

1. Students will weld fillet joint in overhead position to study guide specifications.

2. Students will observe all safety precautions during accomplishment of projects.

EVALUATION:

1. Students projects will be checked during welding process for proper welding procedure and preparation of material. Assistance will be given when necessary.

2. Instructor will check students welds.

END OF DAY SUMMARY

SUMMARY:

1. Overhead welding
2. Weld metal transfer
3. Electrode and current
4. Welding technique
5. Practice shop safety
6. Safety equipment (personal)

CTT ASSIGNMENT
POI ITEM 2a

72A

DAY 4

ASSIGNMENT:

1. Review: CLASS NOTES
2. Review: 3ABR53131 SG-402
3. Review: TO 34W4-1-5
4. Modern Welding Handbook (Chapter 5,)

CTT

Refer to objective 2a

INTRODUCTION TO NEW DAYS INSTRUCTION

1. Evaluate CTT assignment critique missed items.
2. Remotivation.

. Review:

1. Overhead position welding
2. Weld metal transfer
3. Electrodes and current
4. Welding technique
5. Shop safety
6. Safety equipment (personal)

. Overview - Fillet welds in Overhead Position

APPLICATION

1. Students will weld fillet joint in the overhead position to TO 34W4-1-5 specifications.
2. Students will observe all safety precautions during accomplishment of projects.

EVALUATION:

1. Students projects will be checked for proper welding procedure and preparation of material. Assistance will be given when necessary.

CONCLUSION Time: 10 min

1. Summary

   a. Electrodes used

   b. Welding technique

   c. Forces (Gravity and gas expansion)

   d. Safety (Shop and health)

   DAY 5

2. CTT Assignment: Students will read/review following assignment. After assignment will answer questions with 75% accuracy. Read 3ABR53131-SG-403 (POI Item 3a, POI Time 2 hrs).

3. Remotivation:

4. Closing Statement:

LESSON PLAN (Part I, General)

APPROVAL OFFICE AND DATE: TWSTI 8 Oct 75 Chas Ezell Lead	INSTRUCTOR:
COURSE NUMBER: 3ABR53131	COURSE TITLE: Metals Processing Specialist
BLOCK NUMBER: IV	BLOCK TITLE: Special Metallic Arc and Resistance Welding Applications
LESSON TITLE: Pipe Joints	

LESSON DURATION		
CLASSROOM / Laboratory	Complementary	TOTAL
D & D 1 hr/Perf 5 hrs	2 hrs	8 hrs

POI REFERENCE		
PAGE NUMBER	PAGE DATE	PARAGRAPH
29	23 Sep 1975	3

STS/CTS REFERENCE	
NUMBER	DATE
STS 531X1	31 May 1975

SUPERVISOR APPROVAL

SIGNATURE	DATE	SIGNATURE	DATE

PRECLASS PREPARATION

EQUIPMENT LOCATED IN LABORATORY	EQUIPMENT FROM SUPPLY	CLASSIFIED MATERIAL	GRAPHIC AIDS AND UNCLASSIFIED MATERIAL
1. Arc Welding Booth Complete 2. Power Saw 3. Grinder	Toolkit	None	1. 3ABR53131-SG-403 2. TO 34W4-1-5 3. Modern Welding (Chapter 18) 4. Chart: Pipe Welding - Welding Sequence CAFB 63-502

CRITERION OBJECTIVES AND TEACHING STEPS

a. Given metallic arc welding equipment and carbon steel pipe specimens, set up and weld pipe joints with 100% penetration, free of undercut, overlap, and slag inclusions, for a total combined distance of no less than 3/4 of the length of the weld. All shop safety, good housekeeping and fire prevention measures must be observed.

Teaching steps are listed in Part II.

ATC FORM AUG 72 770

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INTRODUCTION

Time: 10 min

1. Attention:

2. Review: During our last lesson we learned and applied the fundamental principles of overhead welding.

3. Overview: Upon completing this lesson you will understand and apply the principles and techniques of welding pipe with metallic arc welding.

4. Motivation:

BODY

Time: 5 hrs 40 min

PRESENTATION

Refer to Objective #1

1. General Information
   - a. Tubular section most efficient
   - b. Transferring materials from place to place without loss
   - c. Construction Field
     - (1) Engine mounts
     - (2) Frames, platforms, jigs
     - (3) Petroleum industry
       - (a) Pipe lines
2. Advantages of welded joints
   - a. Permanently tight
   - b. Greater strength
   - c. Less resistance to flow

d. More pleasing appearance

e. Easier and cheaper

f. Simplification of design

3. Butt joint

a. Most common joint in pipe

(1) a crack is a butt joint

b. Types of joints

(1) Square edge

(2) Bevel

c. Wall thickness less than 3/16

(1) One Pass

(2) No Bevel required

(3) Square edge butt joint

d. Wall thickness 3/16 - 3/4"

(1) One pass per 1/8" metal thickness

(2) Bevel 30-37 1/2°

(3) 1/16" lip inside wall of pipe

(4) Light material bevel on grinder

(a) Use face shield

e. Wall thickness 3/4 and up

(1) One pass per 1/8" metal thickness

(2) Bevel 20°

(3) 1/16" lip inside wall of pipe

(4) Bevel with oxyacetelene torch

4. Backing rings

a. Ring shaped strap fitted inside pipe

(1) Plain flat strap

(2) Small lip for spacing 1/16"

(3) Made out of brass or bronze

(a) Removed after welding

(b) Welded metal won't adhere

(4) Made out of base material

(a) Left inside pipe

b. Uses of backing rings

(1) To secure 100% penetration

(2) Prevention of slag and globules from falling inside pipe

(3) Alignment of pipe ends

(a) Keep the pipe straight

c. Not ordinarily used

(1) Shop fabrications

(2) When internal cleaning is required

d. Reinforcement

(1) 1/16 maximum reinforcement

(2) Avoid excessive

(a) Can cause undesirable stress concentrations

e. Template

(1) Used to lay out work

(2) To insure proper fit-up

f. Wrinkle Bending

(1) Can be used on all sizes and thickness of pipe

(2) An oxyacetelene torch is used for heat

(3) Easy to correct mistakes

5. Welding Procedure

a. Clean all surfaces and surrounding areas 1/4" back from edges

b. Remove all:

(1) Rust — Use Mechanical Cleaning

(2) Scale

(3) Oil and grease — Use Chemical cleaning

(4) Paint

6. Alignment and tack welding

a. Use of backing rings

b. Suitable fixtures

c. Proper welding sequence

d. At least 4 tack welds

(1) 2-3 T length

(2) 100% penetration

7. Practice shop safety in performance of required tasks

a. No horse play

b. No smoking

c. Maintain clean area and clean daily

d. Inspect cables

(1) Cracks

(2) Frayed wires

Utilize Health and safety equipment

a. Welding helmet and eye protection

(1) Check daily

(a) For cracks

(b) Proper shade size #10

b. Gloves

c. Clothing suitable for job

(1) High top boots

(2) Long sleeved shirts

(3) Aprons

(4) Leathers

d. Use guards on machinery

(1) Face shields

APPLICATION

Given material student will

a. Prepare the metal

b. Set up joint for welding

c. Weld pipe to specification of TO 34W4-1-5

2. Student will observe all safety precautions in the accomplishment of project

EVALUATION

1. Student project will be checked for proper preparation and welding procedures.

2. Assistance will be given when necessary.

3. Instructor will check students welds.

CONCLUSION Time: 10 min

Summary

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1. Review
   a. Preparation of pipe
   b. Pipe welding techniques
   c. Shop safety
2. Assignment
   a. Review 3ABR53230-SG-404
   b. Review notes taken in class
   c. Complete 3ABR53230-WB-404

LESSON PLAN - Part I (General)

APPROVAL OFFICE AND DATE	DISTRIBUTION
TWSTI 29 Oct 70, Richards	
COURSE NUMBER: 3 ABR53131	COURSE TITLE: Metals Processing Specialist
BLOCK NUMBER: IV	BLOCK TITLE: Special Metallic Arc and Resistance Welding Applications
LESSON TITLE: Heat and Corrosion Resistant Ferrous Alloys	

LESSON DURATION

CLASSROOM / Laboratory	Complementary	TOTAL
D & D 2 hrs/Perf 6 hrs	2 hrs	10 hrs

POI REFERENCE

PAGE NUMBER	PAGE DATE	PARAGRAPH
30	23 Sep 1975	4

STS/CTS REFERENCE

NUMBER	DATE
STS 531X1	31 May 1975

SUPERVISOR APPROVAL

SIGNATURE	DATE	SIGNATURE	DATE

PRECLASS PREPARATION

EQUIPMENT LOCATED IN LABORATORY	EQUIPMENT FROM SUPPLY	CLASSIFIED MATERIAL	GRAPHIC AIDS AND UNCLASSIFIED MATERIAL
1. Arc Welding Booth Complete 2. Power Shears	Consolidated Toolkit	None	1. 3ABR53131-SG-404 2. TO 34W4-1-5 3. Modern Welding (Chapter 18)

CRITERION OBJECTIVES AND TEACHING STEPS

a. Given metallic arc welding equipment and heat and corrosion resistant ferrous alloy specimens, set up and weld butt joints with 100% penetration. free of underent, overlap, and slag inclusions for a total combined distance of no less than 3/4 of the length of the specimen, excluding the first 1/2 inch start and the last, 1/2 inch finish. All shop safety, good housekeeping, and fire prevention measures must be observed.

Teaching steps are listed in Part II.

INTRODUCTION Time:

Attention:

Review: During our last lesson, we covered the principles of pipe welding, types of joints and electrodes. Evaluate CTT assignment and critique missed items.

Overview: Upon completion of this lesson you will understand and apply the principles and techniques of welding heat and corrosion resistant ferrous alloys.

Motivation:

BODY Time:

PRESENTATION

Refer to objective #14a

1. Welding heat and corrosion resistance ferrous alloys

   a. Stainless steels most commonly used and will be discussed now are:

      (1) Chromium stainless

         (a) Not recommended for welding

         (b) Subject to rapid grain growth

         (c) Will not respond to heat treatment (grains)

         (d) After welding, have very little ductility

(2) Chromium nickel, Austenitic Stainless Steel

(a) Highly recommended for welding

(b) After welding, extremely tough and ductile

1 Highly suitable for aircraft parts

2 321 & 347 are used for aircraft parts

b. Metallic arc welding is generally used in fabrication and repair of Stainless Steels

(1) Metallic arc gives instant heating

(a) Quickly brought to melting temp of 2690°F

(b) Surrounding metal comparatively cold

1 1000° - 1500°F

2 Heat affected zone

(2) Don't hold at melting temp. too long

(a) If metal is over-heated

1 Warpage occurs

2 Loss of corrosion resistance

3 Undesirable grain growth

(3) Arc welding of Stainless Steel is recommended for it decreases carbide precipitation

(a) Carbide precipitation

1 Free carbon comes out of solution and forms along grain to boundaries

(b) Electrode covering provides a fluxing action - gas protective shield

1 To protect the weld from oxidation

(c) Various electrode combinations available

1 For various alloys combinations

c. Selection of electrode, polarity and current

(1) Military specification (MIL-E-6844)

(a) Color marking

1 347 Electrode

a 19-9

(b) 19% Chromium

(c) 9% Nickel

1 Primary - yellow

2 Secondary - Blue

(2) Manufactures stamp number on rod

(3) Manufactures take into consideration certain elements are lost as they pass through arc

(a) Compensate for loss by increase in volatile elements

(b) When welding 18-8 steel a 19-9 rod is used

(c) Columbium is added to S.S. as a stabilizing agent

(d) 30% of Columbium is lost during welding

(e) Titanium will not transfer across arc

(4) Low current DC with RP most generally used

(a) Place the hot end at the electrode tip
(b) A lower current is used for Stainless Steel because of its lower heat conductivity

d. Welding procedures for Stainless Steel Butt, Joint

(1) Preparation of metal

(a) Clean
(b) Bevel

(2) Set up proper spacing and tack weld

(a) For good penetration
(b) Alignment of parts

(3) Hold proper arc length and angle to insure good fusion

(a) Keep weaving down to a minimum

e. Weld characteristics

(1) Butt joint

(a) Spacing - 1/16"
(b) Penetration 100%
(c) Reinforcement 1/16"
(d) Bead width 3-4T
(e) Electrode angle 20°

(2) No overlap, undercat or slag inclusions

f. Utilize health and safety equipment

(1) Eye protection

(a) #10 lens
(b) Arc helmet
(c) Check lens for cracks

(2) Wearing suitable clothing

(a) High top boots
(b) Long sleeved shirt
(c) Leather aprons
(d) Gloves

g. Practice shop safety in performance of required tasks

Note: Pages 86-87 have been omitted.
However, all material is included.

(1) Daily clean-up

(2) No smoking in lab

(3) Check cables for cracks or frayed wires

(4) Use protective clothing when using power equipment

(a) Face shield

APPLICATION

Given material and equipment for welding a butt, tap, tee, joint in stainless steel, the student will:

a. Prepare joints for welding

b. Weld joints according to specifications of TO 34W4-1-5.

Student will observe all safety precaution during accomplishment of project.

EVALUATION

Student projects will be checked for preparation of material and welding procedures. Assistance will be given when necessary.

END OF DAY SUMMARY

ummary:

1. Stainless steels types
2. Metallic Arc Welding
3. Selection of Electrode, Polarity current
4. Welding Procedures
5. Weld characteristics
6. Shop safety
7. Safety equipment

DAY 7
CTT Assignment
POI Item 5a
POI Time 2 hrs

1. Read 3ABR53131-SG-405.
2. Answer questions at end of chapter 405.
3. Review TO 34W4-1-5
4. Modern Welding Handbook (chap 18, pages 28 - 31)

INTRODUCTION TO NEW DAY'S INSTRUCTION

Remotivation: Refer to objective 4a

Review:

1. Evaluate CTT assignment and critique missed items.
2. Types of stainless
3. Metallic arc welding
4. Selection of electrode, polarity current
5. Welding procedures
6. Weld characteristics
7. Shop safety
8. Safety equipment (personal)

Overview - Welding Heat & Corrosion Resistant Ferrous Alloys
APPLICATION

1. Students will weld stainless steel sheet to study guide specification.
2. Students will observe all safety precautions during acomplishment of projects.

EVALUATION:

1. Students' projects will be checked for proper welding techniques and procedures.

2. Assistance will be given when necessary.

3. Instructor will check students welds.

CONCLUSION Time:

1. Summary

   a. Type of Stainless Steel

   b. Selection of electrodes, polarity and current

   b. Cleaning and repairs

   d. Types of joints

   e. Safety

2. Assignment: Given at End of Day Summary

3. Remotivation:

4. Closing Statement:

LESSON PLAN (Part I, General) 91

APPROVAL OFFICE AND DATE: TWSTI	INSTRUCTION:
COURSE NUMBER: 3ABR53131	COURSE TITLE: Metals Processing Specialist
BLOCK NUMBER: IV	BLOCK TITLE: Special Metallic Arc and Resistance Welding Applications

LESSON TITLE: Cast Iron

LESSON DURATION

CLASSROOM/Laboratory	Complementary	TOTAL
D & D 1 hr/Perf 3 hrs	2 hrs	6 hrs

POI REFERENCE

PAGE NUMBER	PAGE DATE	PARAGRAPH
31	23 Sep 1975	5

STS/CTS REFERENCE

NUMBER	DATE
STS 531X1	31 May 1975

SUPERVISOR APPROVAL

SIGNATURE	DATE	SIGNATURE	DATE

PRECLASS PREPARATION

EQUIPMENT LOCATED IN LABORATORY	EQUIPMENT FROM SUPPLY	CLASSIFIED MATERIAL	GRAPHIC AIDS AND UNCLASSIFIED MATERIAL
1. Arc Welding Booth Complete 2. Power Saw 3. Grinders	Consolidated Toolkit	None	1. 3ABR53131-SC-1405 2. TO 34W4-1-5 3. Modern Welding (Chapter 18)

CRITERION OBJECTIVES AND TEACHING STEPS

a. Given metallic arc welding equipment and gray iron castings, set up and weld butt joints with 100% penetration, free of undercut, overlap, and slag inclusions, for a total combined distance of no less than 3/4 of the length of the specimen excluding the first 1/2 inch start and the last 1/2 inch finish. All shop safety, good housekeeping and fire prevention measures must be observed.

Teaching steps are listed in Part II.

INTRODUCTION

Time:

ATTENTION:

REVIEW: During our last lesson, we covered the characteristics and types of heat and corrosion resistant ferrous alloys. We also covered the principles and techniques of welding heat and corrosion resistant ferrous alloys. Evaluate CTT assignment and critique missed items.

OVERVIEW: Upon completion of this lesson, you will understand and apply the principles and techniques of welding cast iron.

MOTIVATION:

BODY

Time:

PRESENTATION

Refer to Objective #5a

1. Weld butt joint in gray iron casting

   a. General information

      (1) Cast iron contains

         (a) Carbon - 1.7 - 4.5%

         (b) Iron - 91 - 94%

         (c) Silicon - Remainder with alloying elements

      (2) Types of Cast Iron

         (a) White cast iron

            1 Contains carbon in solution combined form

            2 Silvery and white appearance when broken, no free graphite

            3 Hard and brittle

               a Used in machinery not subject to shock

b Produced by quenching rapidly from molten state

(b) Malleable Cast Iron

1 Will bend before breaking

2 Suitable for use where shock occurs

3 Produced by prolonged annealing of white cast iron

(c) Grey Cast Iron

1 Most common type used

2 If broken the surface appears grey and nearly covered with free graphite

3 Produced by slow cooling in sand from molten state

(3) Characteristics of Cast Iron

(a) Hardness

(b) Brittleness

(c) High Compression strength

(d) High Shock, wear and corrosion resistance

(e) Tendency to crack at quick temperature changes

(f) Not mallable at any temperature

(4) Metallic Arc Welding of Cast Iron

(a) Repair of small parts

1 Mild steel electrode designed for cast iron

a Strong cast ferroweld

b Produces a non-machonable weld

2 Heavy coated 18-8 Electrode

3 If machining is necessary use a ni-rod or ni-cast rod

(b) Repair of larger parts

1 Pre-heat to reduce danger of cracking

a 1500° - 2000°F a dull red color

(5) Preparation of Metal

(a) Edges of joint bevel to form 60° angle (included)

(b) 3/32 spacing for lip on bevel

(c) Drill a small hole at each end of crack before welding-prevent crack from spreading

(d) Studding

1 Where maximum strength is desired

2 Place steel studs 1/4 - 3/8" dia. into part, project 3/16 - 1/4 above and weld around

3 Grooves are used when studding is not applicable

(6) Welding Procedures

(a) Reverse polarity with minimum current setting

1 80-110 amps - 1/8 6010 Electrode

(b) Stringer beads of 1" length

1 Allow each bead to cool before continuing

2 Peen each bead to

a Relieve stresses

b Reduce the danger of cracking

3 Clean each bead free of slag

4 Use small dia. electrode

a A smaller molten pool better control

5 Keep weaving down to a minimum

6 Hold a long arc

a Set start on 7 1/2

(7) Carbon Arc Welding

(a) Single carbon arc using cast iron filler rod

1 Use a flux

2 Slow cooling produces a machinable weld

(b) Twin carbon arc for brazing of cast iron

2. Utilize Health and Safety Equipment

a. Eye Protection

(1) #10 lens

(2) Arc helmet

(3) Check lens for cracks

b. Wearing suitable clothing

(1) High top boots

(2) Long sleeved shirt

(3) Leather aprons

(4) Gloves

3. Practice shop safety in performance of required tasks

   a. Daily clear up

   b. No smoking in lab

   c. Check cables for cracks or frayed wires

   d. Use protective clothing when using power equipment

      (1) Face shield

APPLICATION

1. Students will weld butt joints in gray iron castings to TO 34W4-1-5 specifications.

2. Students will observe all safety precautions during accomplishment of projects.

EVALUATION

1. Students projects will be checked for proper preparation of joint and according to TO 34W4-1-5 specifications.

2. Assistance will be given when necessary.

3. Instructor will check welds.

CONCLUSION

1. End of Day Summary

   a. Types of cast iron

   b. Characteristics of cast iron

   c. Welding procedures

   d. Safety equipment

   e. Shop Safety

   f. Weld characteristics

g. Selection of electrode, polarity and current

2. CTT ASSIGNMENT: POI Items 6a, b, c, d, e
DAY 8 POI Time 2 hrs

1. Read 3ABR53131-SG-406.

2. Answer questions at end of chapter.

3. Remotivation:

3. Review TO 34W4-1-5.

4. Closing Statement:

4. Modern Welding Handbook (chap 9, 13, 14 & 20)

LESSON PLAN (Part I, General)

APPROVAL OFFICE AND DATE	INSTRUCTOR
TWSTI 8 Oct 75 Reichard	
COURSE NUMBER	**COURSE TITLE**
3ABR53131	Metals Processing Specialist
BLOCK NUMBER	**BLOCK TITLE**
IV	Special Metallic Arc and Resistant Welding Applications

LESSON TITLE
Hard Surfacing, Cutting, and Resistance Welding

LESSON DURATION

CLASSROOM/Laboratory	Complementary	TOTAL
D & D 2 hrs/Perf 8 hrs	2 hrs	12 hrs

POI REFERENCE

PAGE NUMBER	PAGE DATE	PARAGRAPH
32	23 Sep 1975	6

STS/CTS REFERENCE

UMBER	DATE
STS 531X1	31 May 1975

SUPERVISOR APPROVAL

SIGNATURE	DATE	SIGNATURE	DATE
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PRECLASS PREPARATION

EQUIPMENT LOCATED IN LABORATORY	EQUIPMENT FROM SUPPLY	CLASSIFIED MATERIAL	GRAPHIC AIDS AND UNCLASSIFIED MATERIAL
1. Spot Welder 2. Foil Welder 3. Tensile Tester	None	None	1. 3ABR53131-SG-406 2. TO 34W4-1-5 3. Modern Welding (Chapters 9, 13, 14 and 20)

CRITERION OBJECTIVES AND TEACHING STEPS

a. Given a list, identify procedures pertaining to hard surfacing various metals with 75% accuracy.

b. Using a list, identify procedures relating to metallic arc cutting operations with 75% accuracy.

c. Given welding equipment and ferrous and non ferrous metal specimens, set up and operate resistance spot welding equipment IAW Chapter 13 of Modern Welding. All shop safety, good housekeeping and fire prevention measures must be observed.

d. Given tensile test equipment and finished welds while observing all shop safety, set up and test resistance spot welds for strength, porosity, nugget size and shape. Two of three welds must conform to the proper strength requirements, nugget size, and shape, and be free of porosity, IAW Chapter 13 and 14 Modern Welding.

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LESSON PLAN (Part I, General) CONTINUATION SHEET

CRITERION OBJECTIVES AND TEACHING STEPS (Continued)

e. Given equipment, while observing all shop safety measures, perform operator maintenance of resistance spot welding machines IAW TO 34W4-1-5.

Teaching steps are listed in Part II.

INTRODUCTION Time:

ATTENTION:

REVIEW: During our last lesson we covered the characteristics and types of cast iron. We also covered the principles and techniques of welding cast iron.

OVERVIEW: Upon completion of this lesson, you will understand and apply the principles and techniques of welding cast iron.

MOTIVATION:

BODY Time:

PRESENTATION

Refer to objective #1

1. Hard surfacing, cutting and resistance welding
    a. Hard surfacing
        (1) Applying a hard metal to a softer one
        (2) Applied to many parts and equipment
            (a) Farm and heavy equipment
            (b) Snow plows, railroad rails
            (c) Home Tools
        (3) Basically the same as oxyacetylene hard surfacing
            (a) Differs in method of application (ARC)
        (4) Advantages of hard surfacing
            (a) Increase the life of a part 2-25 times

(b) Resistance to

1 Wear

2 Abrasion

3 Corrosion

4 Impact

(5) Three general groups

(a) Ferrous alloys-iron base

1 Group 1&2

(b) Non-ferrous alloys

1 Small amount of iron-group 3

(c) Diamond substitute

1 Groups 4 & 5

a Powdered or tubes

(6) Method of application

(a) Metallic arc

(b) Carbon arc

(c) Oxyacetylene

b. Hard surfacing can be used on

(1) Low and medium carbon steels .50% or less

(2) High carbon steels

(a) Heat treated before and after to remove brittleness and prevent cracking

(b) If heat treating cannot be done, use the transition method

1 18-8 rod to build up, then hard surface

(3) Almost all ferrous metals

(4) Low alloy steels - heat treated after

(5) Mangenese steels, 11-14% Manganese

(a) Avoid overheating

(b) Peen after welding to relieve stresses

(6) Stainless Steels

(a) Maintain corrosion resistant properties

(7) Cast Iron (gray and alloy cast)

(a) Melts lower than stainless steel

(8) Malleable Iron

(a) Reheat to remove sub-surface brittleness

(b) 1500°F

(9) Monel metal

(10) In some cases, heavy sections of brass, bronze and copper

(a) Preheat to a red heat then apply group 3 alloys

c. Hard surfacing cannot be applied to:

(1) Thin sections of

(a) Brass

(b) Bronze

(c) Copper and its alloys

(2) Aluminum and its alloys

(3) High speed steels

(a) Already as hard as they can be

d. Alloys used for hard surfacing

(1) Classified into five groups

(a) Gr. 1-80% or more of iron

(b) Gr. 2-50% to 80% iron

(c) Gr. 3-non-ferrous alloys

(d) Carbide material up to 95% tungsten carbide

(e) Pure crushed tungsten carbide

(2) No single hard surfacing material is satisfactory for all applications

(a) Depends on base metal and desired surface

1 Hardness

2 Toughness

3 Shock and wear resistance ex. anvil after hard surfacing

e. Metal Preparation

(1) Cleaning - Mechanical

(a) Machining

(b) Grinding

(c) Filing

(d) Sandblasting and wire brushing as a last resort only

1 Because grease and oil are driven into the metals pores

(2) Round off thin edges to prevent overheating

f. Preheating

(1) Same precautions as for welding

(2) Heat treated steels are to be annealed

(a) Re-heat treated

(3) After heat treatment use a slow quench

(a) Oil

g. Thickness of hard surface will range from 1/16" to 1/4"

(1) Bead width 3/4T to 1 1/4T

(2) If a greater build up is required, use group 1 alloys then finish with group 2 or 3

h. Metallic Arc Welding

(1) Bare or coated electrodes use DCRP

(a) Except some of groups 4 & 5

(2) Flux coating

(a) Assures good penetration

(b) Helps stabilize the arc

(c) Prevents oxidation

1 Provides slag coating

(3) Hold a long arc

(4) Bare electrodes

(a) Produce heavy beads

i. Carbon arc welding

(1) Can be used for all metals that can be metallic arc welded

(2) Straight polarity

(a) Non-consumable electrode

(b) Used for some of the group 4 and 5 powdered and granulated alloys

2. Arc Cutting

a. Used to cut non-ferrous material and cast iron

b. Used in welding shops

(1) Used in scrap yards for salvage work

(2) Fast and economical

c. Three arc cutting processes

(1) Metallic arc

(a) AC or DC straight polarity

(2) Carbon arc

(a) DC straight polarity

(3) Oxy-Arc

(4) All are faster than oxy-acetylene

(a) But leave a rougher cut

d. Application

(1) Metallic Arc

(a) Flat type, heavy coated electrode

1 E-6012 or E-6013

(b) Coating serves as insulator

1 To prevent rapid melting of electrode

(c) Current setting much higher than for welding

diameter	-	current
1/8"		200 amps
5/32"		300 amps
3/16"	-	400 amps

(d) Cutting procedures

1 Safety clothes are worn

2 Remove all combustible material

3 Start from top of part to bottom

4 AC or DCSP

(2) Carbon Arc Cutting

(a) DCSP, high current, long arc

(b) Carbon electrode

1 Tapered 6-8T

(c) Cut from top to bottom

(3) Oxy arc

(a) Special hollow electrodes

(b) Regular heavy coated electrodes

(c) Carbon electrodes

(d) Holder has oxygen orifice to blow away metal

(e) Speed of travel like oxy-acetylene

1 Jagged cut

(f) Metal is not oxidized as in oxy-acetylene cutting

3. Resistance Welding:

Metals resistance to electricity flow

Metal turns plastic - EXPLAIN

a. Spot welding

(1) Most widely used resistance welding process

(2) Weld is made at one spot between the electrodes

b. Spot welding machines

(1) Rocker arm

(a) Upper arm pivots

(b) Lower arm in fixed position

(c) Air pressure or hydraulic

(2) Press type spot welder moves straight up and down

(a) Lower arm in fixed position

(3) Multiple spot welders

(a) More than one weld - mass production

(b) Used in auto body production

(4) Portable gun spot welders

(a) Where part won't fit in jaws of conventional spot welders

c. Seam welding

(1) Same principle as spot welding - electrodes are copper alloy wheels or rollers

(2) One of the wheels is motor driven

(3) Varied

(a) Current

(b) Speed of travel

(c) Weld space

(4) Looks like continuous weld

(a) Really a series of spot welds

(5) Used on:

(a) Inner combustion chambers

(b) Outer combustion chambers

(c) Fuel tanks

(d) Other liquid or gas tight containers

1 Always test first with scrap metal of the same type as that to be spot welded

d. Spot welding electrodes

(1) High copper alloy

(a) 80% electrical conductivity

(b) Various types of surfaces

(2) Hollow

(a) Water cooled

1 1 gallon per minute

(3) Contact face diameter should equal 4T of plate to be spot welded

(4) Re-dressed regularly with a die-point dresser or emery cloth

e. Metal foil welding unit-vacuum tube welder

(1) Designed to weld metal from .002" - .008" thick

(2) Less heat than spot welders

(3) Adjustable heat and repeat cycle

(4) Designed to weld foil or mesh

(a) Used on insulation blankets on some types of jet engines

(b) To keep heat away from other aircraft parts

(c) Helps to maintain maximum engine performance

(5) Damages

(a) Tears

(b) Snags

(c) Pin holes

1 Cut patch with scissors

(6) Welding

(a) Set single-repeat switch to single

(b) Turn on power and wait for green light to come on

(c) Set current

(d) Hold tapered ground flat against the work to obtain the best possible ground

1 Check for strength

2 Pull patch off if possible

4. Factors to consider for resistance welding

a. Main variables

(1) Current

(a) Heat to obtain plastic state

(2) Pressure

(a) To combine the plates

(3) Time

(a) Long enough for proper fusion

(4) Electrode contact area

(a) Must be 4T

b. Timing periods in seconds

(1) Weld time

(2) Squeeze time

(3) Hold time

(4) Off time

(a) Metal cooled, cycle completed

(b) Electrode released

5. Preparation of metal

a. Very important to get maximum electron flow

b. Emery cloth and acetone

6. Welding carbon steels

a. Easiest of all metals

b. Because of its wide plastic range

c. Welded with a variety of

(1) Current settings

(2) Pressures

(3) Time settings

7. Welding Stainless Steels

a. Easy to weld but time, pressure and current must be controlled

b. Because of carbide precipitation

c. Welded as rapidly as possible

8. Titanium and its alloys

a. Cleaning is most important

(1) Wash in trichlorethylene

(2) Immersion for 10-15 minutes in a concentration of 8% nitric acid and 2% hydro-flouric acid

9. Test spot weld for strength, porosity, nugget size and shape

a. Inspection of outer surface

(1) Smooth and flat

(2) Free of cracks

(3) Free of tip pick up and flash pits

(a) No contamination from electrode

b. Internal inspection

(1) Sheared weld should

(a) Tear away from other plate

(b) Fine grained and round

(c) Rough fused

(2) Hammer and chisel

(3) Microscope is used to determine grain size and check for cracks

(4) Penetration 20 to 80% of T

10. Perform operator maintenance of resistance welder

a. Clean contact surfaces of lower armature with steel wool

(1) Every six months when welding steel

(2) Every month when welding aluminum

(3) Die point dresser and emery cloth

(4) Lubricate swivel arm every eight hours

11. Utilize health and safety equipment

a. For Arc Cutting

(1) #10 or 12 lens

(2) High top shoes

(3) Long sleeved shirt

(4) Leather sleeves and apron

(5) Gloves

b. For resistance welding

(1) Gloves

(2) Face shield

12. Practice shop safety in performance of required tasks

a. Daily clean up

b. No smoking in lab

c. Check area for flammable materials while cutting

d. Check cables for cracks or frayed wires

e. Use protective clothing for cutting, spot welding and when using power equipment in the shop

APPLICATION

1. Given material, students will operate resistance spot welders and foil welders and will weld various types of material to TO 34W4-1-5 specifications. Students will also arc cut and perform minor maintenance on spot welding equipment.

2. Assistance will be given when necessary.

3. Students will observe all safety precautions during welding procedures.

EVALUATION:

1. Students will be checked for preparation of metal, nugget size, penetration and grain size.

2. Students will be checked for cleanness of arc cut.

3. Students will be checked out while performing minor maintenance on resistance welders,

END OF DAY SUMMARY

1. Hard surfacing
   a. Groups
   b. When used
2. Arc Cutting
   a. Types
   b. Principles
3. Resistance Welding
   a. Types
   b. Principles
   c. Maintenance
   d. Weld Characteristics
   e. Selection of electrode sizes

Technical Training

Metals Processing Specialist

BLOCK III
INTRODUCTION TO METALLIC ARC WELDING

5 September 1975

13-6

CHANUTE TECHNICAL TRAINING CENTER (ATC)

This supersedes 3ABR53230-SG-300, 3 January 1973.
OPR: TWS
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Metals Technology Branch
Chanute AFB, Illinois

3ABR53131-SG-301

PRINCIPLES OF OPERATION AND MAINTENANCE OF ARC WELDING MACHINES

OBJECTIVES

After completing this study guide and classroom instruction, you will understand basic electricity and the operating principles as they apply to arc welding machines. You will set up an arc welding machine for welding, and perform operator maintenance.

INTRODUCTION

The electric current used for metallic arc welding is supplied by a machine that converts line voltage of 110, 220, or 440 volts to low voltage, high amperage current. The heat required is generated in the space between a consumable electrode and the basic metal by the current jumping this space and creating an electric arc. The temperature of this arc varies from 5,000° to 10,000°F. Since you must know what controls this arc and why it needs to be controlled, we will discuss the operation and maintenance of the various types of arc welding machines.

INFORMATION

MANAGEMENT OF DEFENSE ENERGY AND RESOURCES

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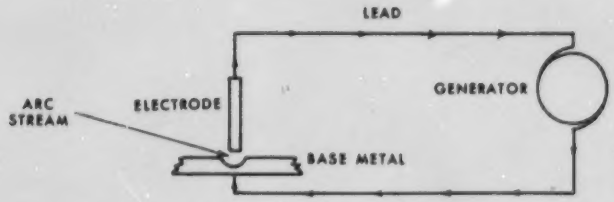


Figure 1. Simplified Diagram of Electric Arc Welding Circuit.

FUNDAMENTALS OF ELECTRICITY IN ARC WELDING

There are basic electrical facts which you should know in order to understand the purpose and use of electricity in arc welding.

Circuit

Electricity cannot flow without a complete conducting path. This path is called a circuit. In arc welding, this circuit is made up of the welding leads, electrode, and the arc stream, as shown in figure 1.

Voltage

Electricity needs a push to move through the circuit just as water does through a pipe. This push is supplied by an electromotive force commonly known as voltage. The voltage is created by an imbalance of electricity. This imbalance is created when the welding generator develops an electrical charge greater than the resistance in the leads. The voltage then forces the electric current through the welding lead and electrode. As the current reaches the end of the electrode, the voltage builds up until, like lightning, it has the necessary push to force the current across the arc gap. The current passing across the arc gap releases energy in the form of heat, causing the molten pool to form almost immediately.

Ampere

In order to control the amount of electricity in any given circuit, it needs to be measured

first. The unit of measurement is called an ampere. An ampere is a measure of the amount of current flowing past a given point in a second.

Ohm

The rate of current flowing in the circuit is partially determined by the amount of resistance. Resistance to current flow is measured in ohms. Each metal has its own amount of resistance. In welding, leads must be made from a metal which has a low resistance. Since copper is one of the best conductors (low resistance), it is used in many electrical appliances, generators, lines, and welding leads. Steel has a high resistance and would become too hot for welding purposes other than its use as an electrode.

Arc Length

When metallic arc welding, the proper length of arc is necessary to concentrate the heat on the work. With a long arc, much of the heat is lost by radiating into the atmosphere. A short arc is more stable, giving more control of the molten pool. With a short arc, vapors from the burning electrode coating surround the electrode metal and the molten pool, preventing air from reaching them.

ARC WELDING PRINCIPLES

When a current-carrying circuit is broken, the current will continue to flow across an opening until the gap becomes too wide. In bridging this gap, the current is carried by superheated gases from the heated atmosphere and particles of metal from the terminals. This will develop an intensely bright light which is called an electric arc. Since the resistance in the arc is very high, a great deal of electrical energy is converted into heat, both in the arc and at the points at which it enters and leaves the terminals. When the proper arc length is used, the metal exposed to it will melt almost instantly. Figure 2 shows the characteristics of the electric arc.

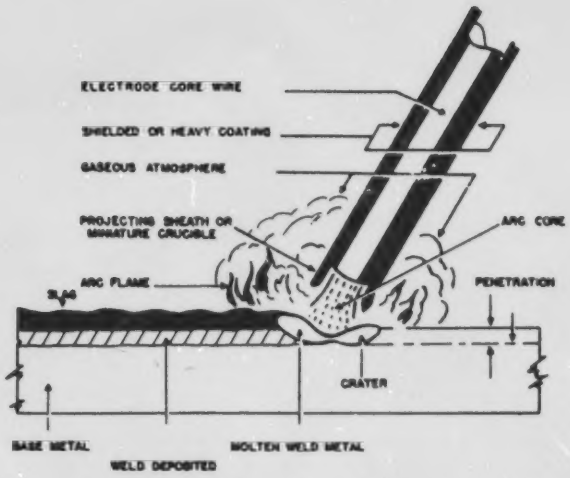


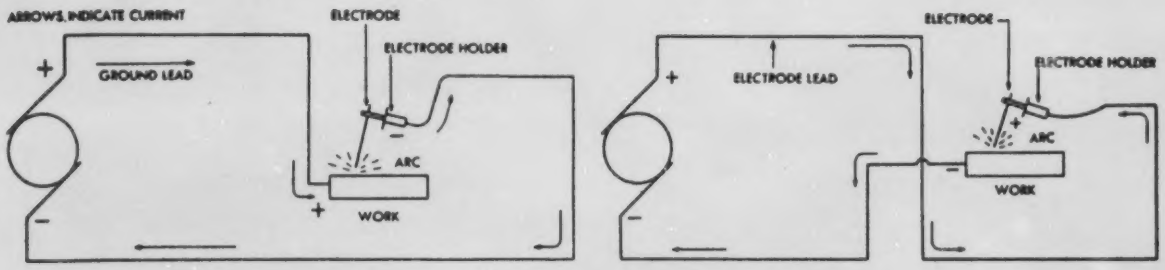
Figure 2. Arc Characteristics of Heavy-Coated Electrode.

Polarity

Every electrical circuit has a positive and a negative terminal or pole. In a direct circuit current (DC), the current flows in one direction only. The line that carries current from the supply is called the positive side, and the line that returns the current to the supply is called the negative side (depending on the theory used). Polarity is simply defined as the direction of current flow. By changing the direction of the current through the work and electrode, the polarity is changed.

In straight polarity, the work is connected to the positive side and the electrode is connected to the negative side. In reverse polarity, the work is connected to the negative side and the electrode is connected to the positive side. Figure 3 illustrates current flow in straight and reverse polarity DC welding.

When using alternating current (AC) welding machines, there is no polarity choice.



A. Straight Polarity. B. Reverse Polarity.

Figure 3. Polarity of Welding Circuits.

Alternating current changes its direction of flow twice each cycle. Because of this, AC machines cannot be used for all types of welding. However, AC welding does have one advantage over DC welding; the changing polarity reduces or eliminates "arc blow."

Weld Metal Deposition

In all metallic arc welding processes, five separate and distinct forces are responsible for the transfer of molten filler metal and slag to the base metal.

GRAVITY. This is the principle which accounts for the transfer of molten metal in the flat position. In the other welding positions, gravity may cause a loss of weld metal and slag because surface tension cannot retain large amounts of molten metal and slag in the weld crater. In these cases, a smaller electrode with lower current settings should be used.

GAS EXPANSION. A gas is produced by the burning of the electrode coating. This gas expands from the heat at the electrode tip and helps to project the molten globules of metal and slag away from the electrode tip and into the molten pool. The electrode coating, extending beyond the tip of the electrode, controls the direction of gas expansion and directs the molten metal into the molten pool.

ELECTROMAGNETIC FORCES. The electrode tip acts as an electrical conductor. Since the molten metal globule is also an electrical conductor, it is affected by the magnetic forces acting at 90 degrees to the direction of current flow. These forces produce a pinching effect on the metal globule and speeds its separation from the end of the electrode. This is particularly helpful in transferring the metal in the horizontal, vertical, and overhead positions.

ELECTRICAL FORCES. The force produced by the voltage across the arc pulls the pinched off globule of metal into the molten pool regardless of the welding position.

SURFACE TENSION. Surface tension is the force which keeps the filler metal and slag in contact with the molten base metal in the arc crater. It helps to retain the molten metal in the horizontal, vertical, and overhead positions, and is a determining factor in the shape of the weld contour.

Magnetic Arc Blow

A phenomenon of DC arc welding is the tendency of the arc to waver as though a blast of air were being blown against it. This trouble is often encountered when welding in corners and at the start and end of butt joints. The arc is forcibly moved by a magnetic field that is set up in the work by the flow of the welding current. The direction and amount of the arc

bending; depends on the direction and strength of the magnetic field. In order to eliminate or minimize this interference, the position of the ground in relation to the arc or the angle to the electrode should be changed. Although these two methods are not the only way to eliminate arc blow, they do work more often than any other method. As you become more proficient in welding, another method may be found which works better.

SELECTION OF CURRENT AND ELECTRODE

The selection of the proper welding current and voltage depends upon the size of the electrode, thickness of the metal being welded, position of the weld, and the experience and skill of the welder. Since several factors may affect the current settings, information published by welding machine manufacturers should only be used as a guide.

One of the difficulties often encountered in learning to strike an arc is having the electrode freeze to the work. This can be overcome by moving the electrode across the work as if striking a match, as shown in figure 4.

After establishing the arc, develop a long arc momentarily to preheat the base metal, then shorten it to the proper length and continue the weld. The proper arc

Figure 4. Procedure for Striking the Arc.

length is approximately the same as the diameter of the electrode and has a characteristic hissing and crackling sound. If the arc is too short, it will sputter, go out intermittently, and the electrode will stick to the work. An arc that is too long causes spattering, loss of puddle control, and poor penetration.

General Procedures

The following are general procedures to be used when arc welding:

1. Clean the surface of the metal to be welded.

2. Uncoil the welding cables. Place the ground plate on the welding table and the electrode holder in its receptacle.

3. Plug in the power cable and start the machine.

4. Grip the electrode in the holder near the end.

5. Pick out a definite spot on the plate, lower the helmet, and strike the arc.

6. Hold a long arc momentarily, then shorten it.

7. Break the arc after depositing a few globules of metal.

8. Continue this procedure until the arc can be struck at the first attempt and at the right spot.

PRECAUTIONS:

1. MAKE SURE THE GROUND CONNECTION ON THE MACHINE IS PROPERLY MADE.

2. AVOID "FLASHING" YOURSELF OR OTHERS.

3. USE PLIERS TO HANDLE HOT METAL.

C.L.A.S.S. Rule

There are five major factors of welding which will greatly affect the quality of the weld. By taking the first letter of each and forming an abbreviation from them, the name C.L.A.S.S. rule was formed. The factors are:

CURRENT SETTING (C). This can affect undercut, overlap, and penetration.

LENGTH OF ARC (L). This affects amount of splatter, bead shape, and penetration.

ANGLE OF ELECTRODE (A). The electrode acts much the same as an oxyacetylene torch in this manner. Undercut, overlap, and improper weld bead contour are common defects caused by improper angle.

SPEED OF TRAVEL (S). Variations of this factor can cause variations in bead height, bead width, undercut, and overlap.

SELECTION OF ELECTRODE (S). The correct selection is important in getting the proper mechanical properties in a weld. Common defects caused by improper selection are loss of corrosion resistance and ductility in the weld.

ELECTRIC ARC WELDING MACHINES

The function of an electric arc welding machine is to provide the source of current necessary for welding. It also provides a means for sustaining and controlling the amount of welding current. These functions are achieved in various ways, depending on the design features of the manufacturer. Although arc welding machines may be classified in various ways, they are either direct current (DC) or alternating current (AC). In recent years, however, electric and selenium plate rectifiers have been developed which operate on AC to produce a DC welding current.

DIRECT CURRENT ARC WELDING MACHINES

DC arc welding machines are suitable for use on all metals. They usually produce more satisfactory results when welding thin materials because of the low current settings required. However, the type of machine best suited for metallic arc welding depends upon many factors. The main difference between AC and DC arc welding is in the lower initial cost and lower operating costs of the AC equipment.

Electric Motor-Driven Generator

The most widely used welding machines are the motor-generator type. These machines operate on electric power and produce direct current of the proper characteristics for arc welding. They consist of a driving motor and a direct current generator. The armature of the generator is mounted on the same shaft as the rotor of the driving motor. The shaft is supported at each end on ball bearings and the machine is made as compact as possible. Two controls for the welding current are provided; one for large increases or decreases, and the other for small changes. Some machines provide a switch for changing polarity; whereas, others require changing the position of the welding cable leads. A pushbutton switch located on the control panel allows convenient starting and stopping of the machine and overload protection for the driving motor. A voltmeter and ammeter permit you to set the machine to the correct current output. Most of these machines are mounted on a chassis so that you can move them around in the shop. They can be mounted either vertically or horizontally. Motor-generator welders are rated by current output in amperes and range from 100 to 1200 amps. A 300 amp welder is the average size used in most Air Force welding shops. These current ratings represent the amount of current which the machine can generate continuously for one hour without exceeding a specific temperature rise. However, they can deliver more than the rated current for a short period without damage to the machine.

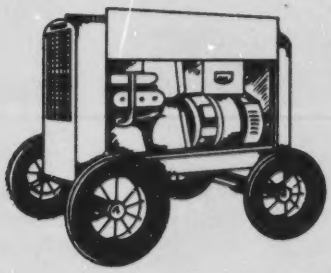


Figure 5. Portable Gasoline Engine-Driven Arc Welder.

Engine-Driven Generator

When an electric power source is not available, a gasoline or diesel engine is used to drive the welding generator. The engine is equipped with an automatic throttle control and a governor to control the power demand on the generator. The complete unit, as shown in figure 5, is usually mounted on a trailer-type chassis

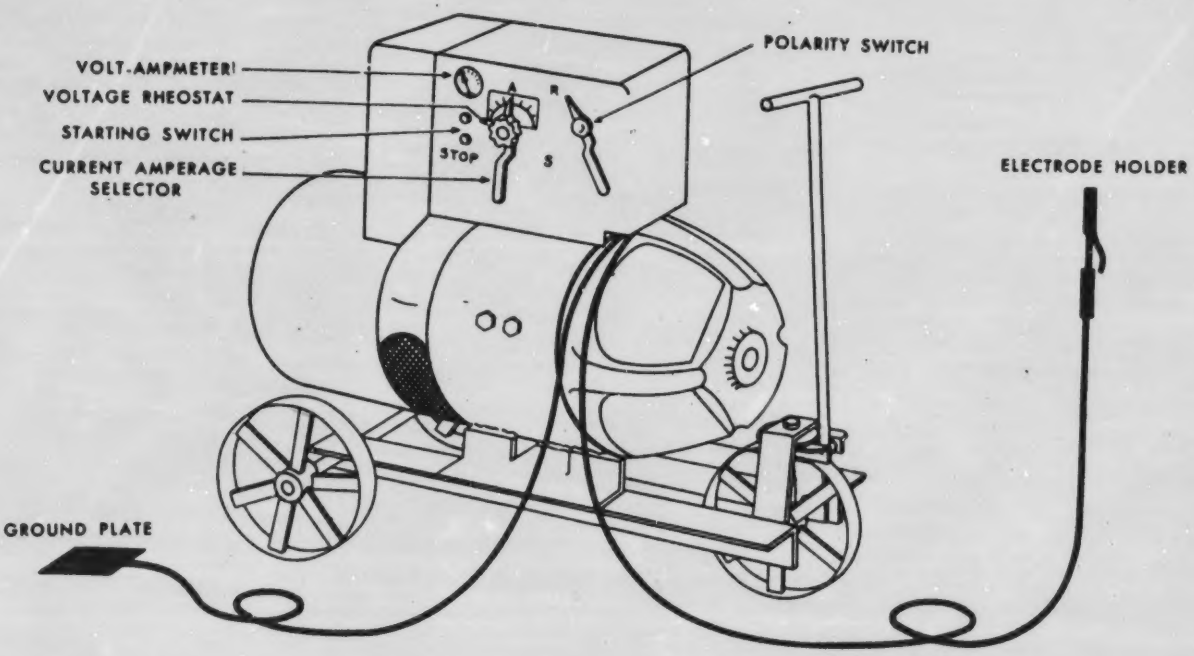


Figure 6. DC Motor Generator (Dual Control) Arc Welding Machine.

and can be towed to the job site.

The voltage from such a generator usually ranges from 15 to 45 volts across the arc, although any setting is subjected to constant variation due to changes in the arc length. Current output may vary from 20 to 800 amps, depending on the type of unit. In most DC welders, the generator is a variable voltage type and is arranged so that the voltage automatically adjusts itself to the demands of the arc. The amperage is adjusted manually and is set to the proper range by either a selector switch or a series of plug receptacles. When both voltage and amperage of the welder are adjustable by manual controls, the machine is classified as a dual control type, as shown in figure 6.

Rectifier Welder

The rectifier welder changes alternating current to direct current for welding. Electronic tubes or selenium plates are used to change (rectify) three-phase alternating current to direct current. There are controls to change the welding current, open circuit voltage, and polarity. The current output of these machines allows a stable arc to be held at any setting from 5 to 75 amps. This allows welding of metals as thin as 1/16" as easily as welding metals 1/4" thick.

ALTERNATING CURRENT (AC) ARC WELDING MACHINES

The two general types of AC arc welders are the transformer and rotating types. Most AC arc welding machines are essentially static transformers. The transformer offers three advantages: (1) low initial cost, (2) low operating cost, and (3) low maintenance cost. Due to the absence of moving parts, the initial and maintenance costs are less than that for DC machines.

Transformer Type

The transformer type of AC welding machine

operates from one phase of the power supply. The primary winding is connected to the power line whereas the secondary winding is connected to the welding cables. Some machines have the transformer windings tapped at intervals to allow changes in the welding current to be made. By using the different taps, you can increase or decrease the current to suit your needs. Other machines have a movable coil or core which is controlled by a handwheel. Current settings are made by either turning the handwheel clockwise or counterclockwise to raise or lower the current setting. These machines are rated by current output and are available with a wide range of current settings. Since these transformers draw current only during the time the weld is being run, they give remarkable economy in power consumption. They are easily adjusted to the required current settings and require very little maintenance.

Rotating Type

The rotating type of welding machine is a motor-generator. It can be combined with a frequency changer to allow the welding machine to be converted to heli-arc operations or to a phase changer to supply auxiliary power for tools or lights. A two-position switch permits selection of either a high or low current. An auxiliary control is used for fine current adjustments.

Accessories

Arc welding machines require certain accessories to make a complete welding outfit.

WELDING CABLES. Welding cables (leads) are rubber covered, multistrand, copper cables made specifically for arc welding. The size of cable used depends on the normal welding current and the distance from the machine to the work. For distances up to 50 feet, a 200 ampere machine should have a No. 2 cable, a 300 ampere machine should have a No. 0 cable, and a 400 ampere machine should have a No. 00 cable.

ELECTRODE HOLDER. The electrode holder is attached to one of the welding cables and has a clamping device for holding the electrode. Various sizes are available according to the amperage capacity of the welding machine.

MAINTENANCE OF ARC WELDING MACHINES

Due to the amount of dust and grit present in all welding shops, proper maintenance of equipment is very important. Although you can perform routine maintenance, a qualified electrician should perform any extensive repairs or adjustments. The following periodic maintenance schedule should help prevent a major breakdown and prolong the life of the equipment. Detailed instructions for the operation, maintenance, overhaul, and the parts catalog for specific types of arc welding machines can be found in the 34W4 series TO entitled "Welding Machines and Related Equipment." An inspection record noting dates and maintenance performed is kept for each machine.

Cleaning and Inspection

A maintenance schedule is set up to keep the welding machine in good operating condition. This maintenance should be scheduled according to how often the machine is used.

On a daily or "as used" basis, the cables, ground, clamp, and electrode holder should be checked for bare wires and loose connections.

On a weekly basis, the welding machine should be checked for loose nuts, bolts, screws, or parts. These components tend to work loose due to the vibrations of the cooling fan and generator.

Air is drawn into the machine by the cooling fan and circulated through passages and around the motor-generator windings. An accumulation of dust in these areas will cause blockage of the air flow and an increase in operating temperatures. Clean out the machine with dry

Figure 7.

compressed air as shown in figure 7. If the machine is greasy, it should be taken apart and thoroughly cleaned. This is done on a monthly basis.

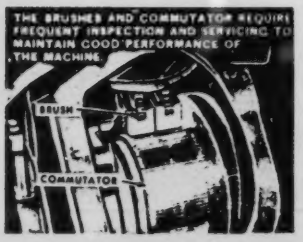

THE BRUSHES AND COMMUTATOR REQUIRE FREQUENT INSPECTION AND SERVICING TO MAINTAIN GOOD PERFORMANCE OF THE MACHINE.
BRUSH
COMMUTATOR

Figure 8.

Electrical Parts

During the monthly inspection, check the condition of the switch points, brushes, commutator, shown in figure 8, and the bearings. Brushes that have worn enough to appreciably reduce their spring tension should be replaced. Brush springs that have been weakened from overheating should be replaced to assure positive brush contact.

Each time the brushes are replaced the commutator should be checked for cleanliness and wear. A commutator in good condition has a deep bronze color. Ridges or pockets on the surface of the commutator should be removed by turning it down on a lathe.

Figure 9.

Electrical switch contacts that are pitted should be sanded smooth (figure 9). Badly burned contacts should be replaced.

The windings of the generator and motor should be inspected once a year. A coat of shellac should be applied if they are dry or cracked.

Lubrication

Welding machines having moving parts should be lubricated at 4 to 6 month intervals depending on the number of operating hours. The more the welder is used, the shorter the time between lubrications. Be sure not to use too much grease since the excess could be thrown onto the commutator or windings and cause deterioration of the insulation and a possible short circuit. Use the grease specified by the manufacturer as found on the data plate or in the Mil Spec.

SAFETY

Eyes

The helmet is your most important item of personal safety equipment. When fitted with the proper lens, it protects you from three types of radiation; heat, light, and infrared and ultraviolet rays. Since the light rays can be harmful to other people in the area, use screens or shields around your work. If it is necessary to weld in an open area, keep all unnecessary personnel away and make sure that your helper has and uses a helmet. Lens shades are determined by the amperage used in welding. A No. 10 shade is satisfactory up to 200 amps; from 200 to 400 amps, a No. 12 shade is used; and for over 400 amps, use a No. 14 shade.

Clothing

Wear gauntlet type leather gloves to protect your hands from heat and sparks. Use a leather apron to protect your clothing from sparks and globules of molten metal. Wear high top shoes and trousers without cuffs. Cuffs can collect hot sparks and molten metal which may ignite your clothing, resulting in serious burns. Never wear torn or ragged clothing since it can catch fire easier and exposed parts of the body may be painfully burned.

Electric Shock

When working in a wet area, be very careful when changing electrodes. Stand on a dry board or some other type of insulating material and BE SURE that the machine is GROUNDED.

Grinder Operation

A grinder is a simple, easy to use tool but should not be taken lightly. If used improperly, it can cause severe eye damage and cuts.

Even if the grinder has a clear shield mounted on it, a face shield is required for eye protection from flying sparks and chips. Safety goggles may be used when a face shield is not available.

A tool rest on the grinder is another piece of safety equipment and should be positioned no more than 1/8" from the grinding wheel. A distance of more than this can cause the wheel to "grab" the metal out of your hand and thus result in a severe cut.

Note: Always let the grinding wheel obtain full rpm before using it.

QUESTIONS

Note: Answer all questions on a separate sheet of paper. DO NOT WRITE ON THIS STUDY GUIDE.

1. How are the cables connected for DCRP?

2. What are electric forces?

3. What determines the type of grease to be used on welding machines?

4. What determines the polarity setting on a welding machine?

5. What encourages the flow of electrons across the arc?

6. What effect does a long arc have on voltage?

7. What is surface tension?

8. What are the amperage and voltage requirements for a welding machine?

9. Where is the heat generated when welding?

10. What determines amperage settings while welding?

REFERENCES

1. TO 34W4-1-1, Welding Theory and Application.

2. Modern Welding (Chapter 6), Arc Welding.

Metals Technology Branch
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3ABR53131-SG-302

IDENTIFICATION AND SELECTION OF ELECTRODES

OBJECTIVES

After completing this study guide and classroom instruction, you will identify and select electrodes using military specifications and AWS numerical and color codes.

INTRODUCTION

The electrodes used for metallic arc welding do the same job as the filler rod in oxyacetylene welding. The major difference between the two rods is the flux coating on the electrode. This flux coating serves to protect the weld from oxidation while it cools. There are two basic types of flux coating with variations of each one. Since these electrodes and coatings are designed for a specific purpose, it is necessary for you to be able to identify them by their number or color code.

INFORMATION

MANAGEMENT OF DEFENSE ENERGY AND RESOURCES

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SHIELDED ARC OR HEAVY COATED ELECTRODES

In order to protect the weld metal from the harmful effects of oxygen and nitrogen in the air surrounding the arc, some form of protection must be provided in the arc stream. Since absorption of the oxygen and nitrogen by the hot weld metal causes brittleness in the weld, the electrodes are designed with a suitable coating to prevent this absorption. The coating produces a gas which keeps the air from the arc and forms slag which acts as a blanket to slow the cooling rate of the molten pool. This helps purify the weld by letting the impurities float to the surface.

Shielded arc or heavy coated electrodes are made from wire which has a definite composition with a heavy coating around the wire. These coatings have been designed to improve the physical properties of the weld deposit, to control arc stability, and to increase the speed and ease of welding in the vertical and overhead positions. These electrodes are manufactured by extrusion, wrapping, heavy clipping, or combinations of these processes. The coating of these electrodes may be either cellulose, mineral, or a combination of both.

Reverse polarity electrodes have a cellulose coating made from wood pulp, sawdust, cotton, or various compositions of rayon. This type of coating protects the weld by forming a gaseous shield as it burns away. This gaseous shield allows the weld to cool and set up faster. This is a distinct advantage when welding in the vertical or overhead positions.

Straight polarity electrodes have a mineral coating made from metallic oxides in the form of natural silicates, such as asbestos, clay, or specially manufactured forms of silicates. This coating protects the weld by forming a blanket of slag which reduces the cooling rate. Figure 10 illustrates the shielding effect of the heavy mineral coating.

Low Hydrogen Electrodes

Hydrogen has a harmful effect on alloy steels such as causing intergranular cracks which are known as hydrogen embrittlement. This condition lowers the fatigue resistance and strength of the metal.

Low hydrogen electrodes deposit a minimum of

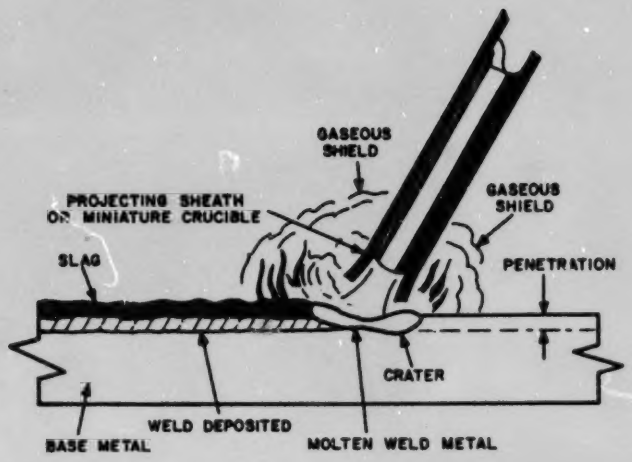

Figure 10. Action of Heavy Electrode Coating.

hydrogen in the weldment. The low hydrogen condition is obtained by using special coverings of lime, titania, and iron powder (AWS numbers ending in 5, 6, 7, or 8).

The electrode conforms to AWSE-6010, E-7016, and E-7018 specifications. It is used on hard to weld steels (free machining), high carbon low alloy steels, and hardenable steels. Although the slag is very fluid, good flat convex beads are easily obtained.

Identification of Electrodes

The American Welding Society (AWS) has established a number and color code system for identification and selection of electrodes. It is absolutely necessary that you understand the system in order to select the proper electrode for the job.

NUMBER CODE. This code is used on mild steel and low alloy electrodes. It can be either a four digit or five digit number. Each digit or group of digits has a specific meaning.

Since the E-6010 electrode is the most common, we will use it as the example of how to interpret this number code.

The letter E designates that this is an electric welding filler rod (electrode). The first two digits "60" indicate the minimum tensile strength in thousandths of pounds per square inch. In this example, the tensile strength of the electrode is a minimum of 60,000 psi.

The third digit "1" indicates the weld position in which the electrode can best be used. This number can be any one of three. The "1" in the example indicates that this is an all position electrode. A "2" would indicate flat and horizontal welding positions, and a "3" would indicate welding in the flat position only.

The fourth digit "0" refers to the type of current to be used and indirectly the type of electrode coating. This digit can be any number from "0" to "8." Table 1 shows the current for some of these numbers. The coating is also given for numbers 5, 6, and 8.

The five digit number gives the same information as the four digit number; however, the first three digits are the tensile strength while the last two are still the position and current selection.

AWS COLOR CODE. This code consists of three markings; primary (end), secondary (spot), and group, as shown in figure 11. The primary and secondary color indicates the composition of the electrode while the group color indicates the type of current. The primary (end) color is on the top of the base or grip end of the electrode. The secondary (spot) color is located on the grip end midway between the end of the electrode and the flux coating. The group color is located on the flux coating just below the grip end of the electrode. The color coding for common electrodes is shown in foldout 1.

0 - DC reverse when third digit is 1.
0 - DC reverse polarity; AC when third digit is 2 or 3.
1 - AC* or DC reverse polarity.
2 - DC straight polarity or AC.
3 - AC* or DC straight polarity.
5 - DC reverse polarity (lime or titania sodium low hydrogen).
6 - AC* or DC reverse polarity (titania or lime potassium low hydrogen).
8 - AC or DC reverse polarity (iron powder plus low hydrogen sodium covering).
*Preferred

Table 1. Electrode Covering Compositions and Current Selection.

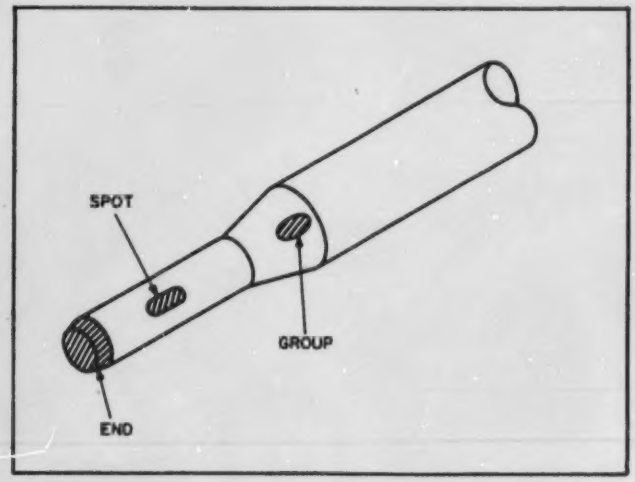

Figure 11. Color Identification Markings.

Characteristics of Common Electrodes

THE E-6010 ELECTRODE. This electrode is the most universally used of all metallic arc welding electrodes. This is because it can be used in all positions and the weld deposit has physical properties at least as good as any other electrode. It is sometimes referred to as the cellulosic type because the coating contains a considerable amount of cellulose, such as wood flour or paper flour, which are combined with other ingredients. These ingredients are added to obtain certain specific qualities, such as volume and fluidity of the slag. The heat of the arc causes the coating to burn and generate large volumes of gases which effectively shield the molten metal from the air and prevent the formation of harmful oxides and nitrides. Good penetration is characteristic of the cellulosic type as well as quick freezing of the weld metal slag. This makes it applicable for vertical and overhead work.

THE E-6011 ELECTRODE. This electrode is designed to perform the same work using alternating current that E-6010 performs on reverse polarity direct current. It is an all-position

electrode which produces more slag than the E-6010. The range of welding current in which various sizes of electrodes can be used satisfactorily is narrower than is the case with E-6010. This means that the welding current controls must be set more precisely. (Basically cellulose type coating.)

THE E-6012 ELECTRODE. This electrode is for use with direct current straight polarity but works very well on alternating current. This is the case with most straight polarity electrodes. Penetration is not deep; consequently, the E-6012 has many advantages on jobs where the "fit-up" is poor. It is also advantageous on light gage material because there is less tendency to burn through than there is with the E-6010 or E-6011. The E-6012 is an all-position electrode which has fast welding speeds and gives less spatter than most other types. The bead profile is not as flat as that from the E-6010 but it is often preferred for horizontal fillets because of the appearance of the weld. (Basically mineral type coating).

THE E-6013 ELECTRODE. This electrode operates on alternating current and fulfills the same purpose as the E-6012 does operating on straight polarity direct current. The coating contains a high percentage of material for stabilizing and maintaining the arc. Penetration is less than that usually obtained with the E-6012 and the spatter loss is low. This electrode has proven to be the most successful for welding light tubular assemblies; therefore, it is used to a great extent in aircraft construction. Although it is often used with straight polarity direct current, the original intention was to pair it with the E-6011 electrode in the same way that the E-6012 is paired with the E-6010.

Classification

Air Force supply catalogs identify arc welding electrodes by military specification numbers rather than AWS classification numbers. The following information is of importance to Air Force welders and can be found in the 34W4 series technical orders.

CLASS A ELECTRODE. This class corresponds to the AWS electrodes whose last two digits are 12 or 13, such as E-6012 or E-6013.

CLASS B ELECTRODE. This class corresponds to the AWS electrodes whose last two digits are 10 or 11, such as E-6010 or E-6011. This type of electrode is used with DC reverse polarity except when specified as an AC electrode. This electrode is normally preferred for good fit-ups and vertical or overhead welding since penetration is deep. This electrode should not be used when heat treatment is required.

CLASS C ELECTRODE. These are alloy steel electrodes. They are to be used in welding of chrome molybdenum and chrome-nickel-molybdenum steels when heat treatment is required. The corresponding AWS electrode specification would be E-7020 or E-10020. This type of electrode is generally used with straight polarity; although, it may also be used with AC current. Only the smaller diameter electrodes (5/64" and 3/32"), are adaptable to all positions. The larger diameter electrodes are generally used for horizontal fillets and flat work where deep penetration is not required.

CLASS D ELECTRODE. This is a companion rod to the class C electrode. It has the same specification and is used where deeper penetration is required. It is used for welding chrome-molybdenum (4135 and 4140) and chrome-nickel-molybdenum (8735 and 8740) steels. These steels require preheating of the parts from 400° to 500°F. The corresponding AWS electrode specification would be E-7030 or E-10030. This type of electrode is generally used with reverse polarity but may also be used with AC current. It is an all position electrode.

Electrode Diameter	Amperes Minimum	Maximum	Standard Electrode Lengths
1/16 in	40	60	8 in
3/32 in	70	90	11 1/2 in
1/8 in	110	135	14 or 18 in
5/32 in	150	180	14 or 18 in
3/16 in	180	220	14 or 18 in
1/4* in	250	300	14 or 18 in
5/16* in	300	425	14 or 18 in
3/8* in	450	550	14 or 18 in

* Diameters, 1/4 in 5/16 in and 3/8 in are for flat position only

Table 2. Currents Used With Gaseous and Slag Type Electrodes.

Selection of Welding Current for Metallic Electrodes

The selection of the proper welding current and voltage depends on three basic factors: (1) the size of the electrode, (2) the thickness of the plate being welded, and (3) the welder's skill. Higher current values and voltages may be used in the flat position welding, more than for vertical and overhead welds with an electrode of the same size. In general, the proper current and voltage requirements, data published by the manufacturers should be used only as a guide.

The mineral coated type of shielded arc electrode, which produces a slag as a shield, requires higher welding currents than the cellulose coated type. The cellulose coated type produces a large volume of gases to shield the arc stream. Table 2 shows the current requirements for the mineral coated or slag-forming electrode and the cellulose coated or gaseous type of electrode. The welding voltage varies from 20 amps for the 3/32" electrodes to 100 amps for the 3/8" heavy-coated electrodes of either the gaseous or slag forming types.

The shielded-arc electrode has replaced the bare and light-coated electrodes for most welding applications. The factors responsible for this are: higher welding speeds, better weld metal quality, and the ability to introduce certain alloying elements into the weld metal through the heavy coatings on the electrode.

QUESTIONS

Note: Answer all questions on a separate sheet of paper. DO NOT WRITE IN THIS STUDY GUIDE.

1. What are the color markings of 6010, 6011, 6012, and 6013 electrodes?

2. What polarities are recommended for 6010, 6011, 6012, and 6013 electrodes?

3. How do the penetration results differ between the 6010 and 6013 electrodes?

4. What are two types of electrode coatings?

5. Which electrode is used for stainless steel?

REFERENCES

1. TO 34W4-1-8, Use of Welding, Brazing and Silver Soldering Electrodes, Rods, and Wires.

2. Modern Welding Handbook (Chapter 5) Electrodes.

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STRINGER BEADS AND BUILDING UP WORN SURFACES

OBJECTIVES

After completing this study guide and classroom instruction, you will apply the welding technique used in running stringer beads to build up flat and worn surfaces.

INTRODUCTION

Although building up worn surfaces is a relatively simple operation, it is one of the most important. Since replacing worn parts with new ones is not always possible, building up a worn surface may be the only way to return a vehicle or an aircraft to a serviceable condition.

INFORMATION

MANAGEMENT OF DEFENSE ENERGY AND RESOURCES

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STRINGER BEADS

Building up a worn surface is done by running successive beads parallel with, and adjoining, to each other and the base metal. This process is used to build up worn parts high enough to allow for machining the part back to its original dimensions. If only a thin layer of filler metal is required, it is added by weaving the electrode to produce a wide bead of thin cross section.

Cleaning Metals and Electrode Angles

One of the first rules of good welding is to maintain a clean working surface. The presence of oil, dirt, or other foreign matter on the metal to be welded may result in such defects as a lack of fusion, porosity, and slag inclusions.

To prepare parts for welding, the surface of the metal must be cleaned. Wire brushing or buffing is usually adequate unless the part is greasy, rusty, or dirty from other causes.

Trichloroethylene in a vapor degreaser should be used to remove grease or oil and a sandblaster or grinder used to remove rust and scale.

Caution: Oil or grease on the metal may result in a porous weld.

In bead welding with coated electrodes, the electrode is tilted 5 to 15 degrees in the direction of travel, as shown in figure 12. Tilting of the electrode provides a clearer view of the crater and aids in controlling the molten slag.

Once the arc is struck, particles of molten metal melt off the end of the electrode and are deposited in the molten crater on the plate surface. This causes the arc to increase in length unless the electrode is fed down to the plate as fast as it is deposited. Good arc welding depends on the development of close control over the motion of the electrode down to and along the surface of the plate while a constant arc length is maintained.

The proper arc length or gap between the end of the electrode and the plate should be approximately equal to the diameter of the electrode used. However, in starting a weld, a long arc is held momentarily in order to preheat the base metal and permit fusion at the beginning of the weld.

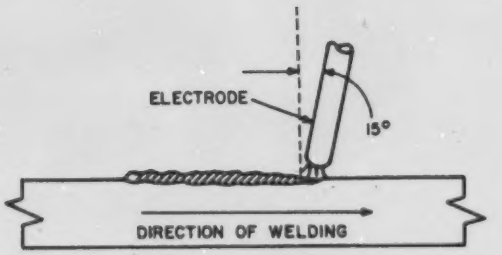


Figure 12. Angle of Electrode in Making Beads.

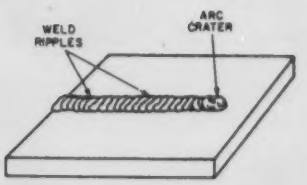


Figure 13. Arc Welded Bead.

The reverse being true at the end of the weld, the arc length is shortened in order to eliminate a crater or depression. Alternate methods of ending a weld are to intermittently restart the weld or reverse the direction of travel for a short distance.

Arc Crater Penetration and Speed of Travel

If the current, polarity, and arc length is correct, the metal melts and forms a pool of molten metal at the point where the arc strikes the plate. This molten metal is forced out of the pool by the blast of the arc. Thus, a small depression is formed in the base metal and the molten metal is piled up around the depression which is referred to as the arc crater, as shown in figure 13.

The size and depth of the crater depends on the current setting, speed of travel, diameter of electrode, and length of arc. The depth of the crater provides a means of observing the "penetration" or depth to which the arc melts into the base metal. The depth of penetration should not be less than 1/16".

The speed of travel is determined by the proportions of the bead desired, current value, and size of the electrode being used. The speed of travel is governed by results observed at the trailing edge of the crater. By closely watching the crater and its trailing edge, the operator can determine the penetration width and height of the reinforcement. Since the speed of travel and current setting are related factors in determining the quality of a weld, the operator must learn to recognize the weld appearance resulting from either factor being wrong. Figure 14 shows the results of various welding speeds and current values.

General Procedures

The following are general procedures used when running beads.

1. Clean the surface of the metal to be welded.

2. Using scrap metal, adjust the controls on the welding machine until the best setting is found.

3. Weld the beads on the plate in the direction of travel, as shown in figure 15.

4. Wire brush each bead before starting the next one.

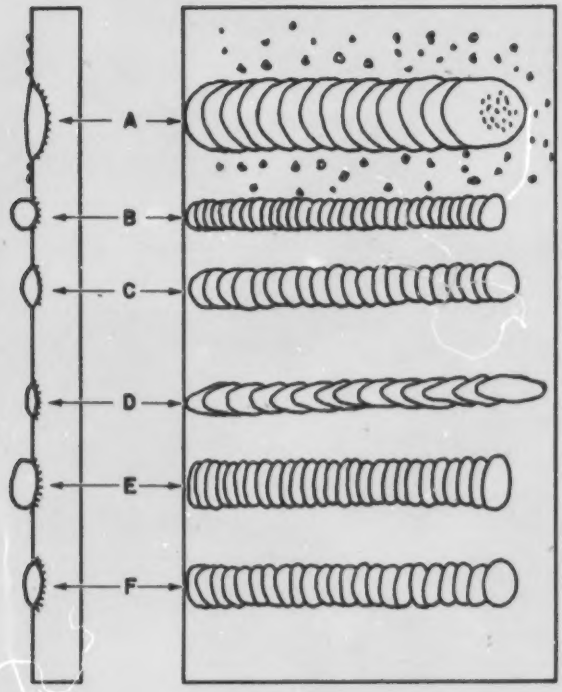
5. Cover the surface with overlapping beads by traveling in the direction of the arrow.

6. Quench the plate often enough to keep it from becoming excessively hot.

BUILDING UP WORN SURFACES

Flat Surfaces

The first stringer bead should encircle the part, as shown in figure 16, so that the other stringer beads can be started and ended with less difficulty. This also reduces the possibility of crater cracks and



A. Current setting too high.
B. Current setting too low.
C. Correct current setting.
D. Rate of travel too fast.
E. Rate of travel too slow.
F. Correct rate of travel.

Figure 14. Results of Various Welding Speeds and Current Values.

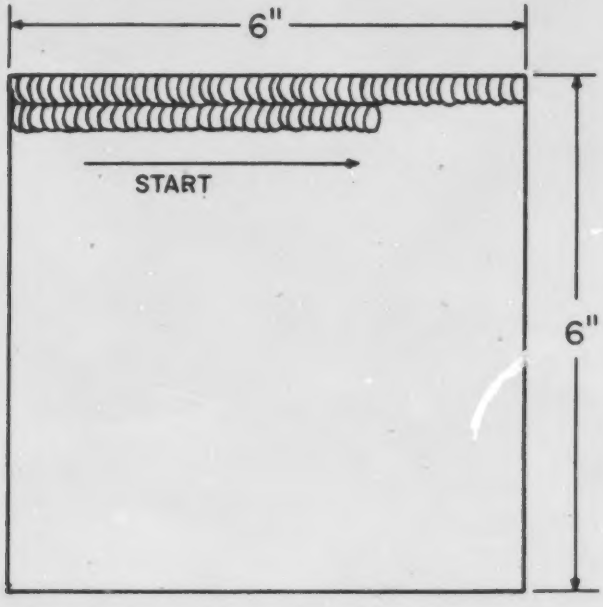


Figure 15. Bead Welding Layout.

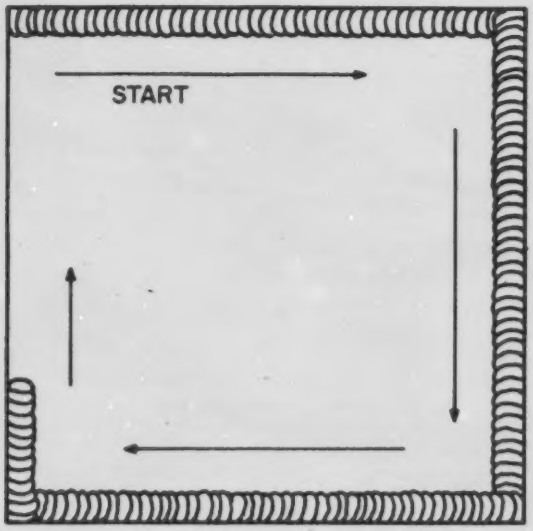


Figure 16. The First Step in Building Up a Worn Surface.

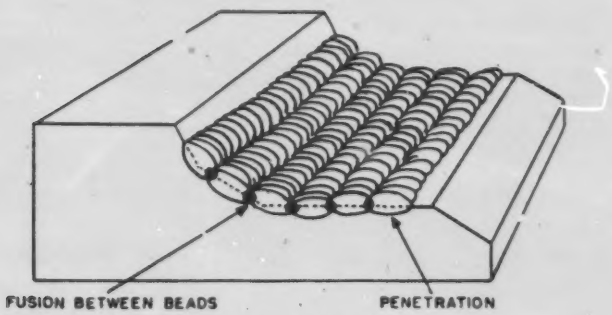


Figure 17. Correct.

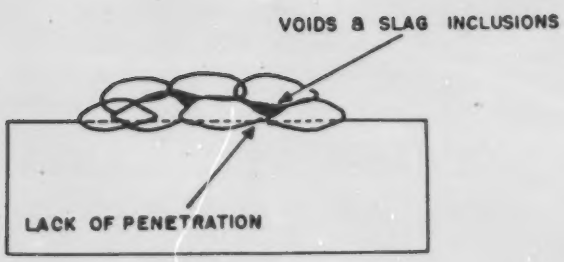


Figure 18. Incorrect.

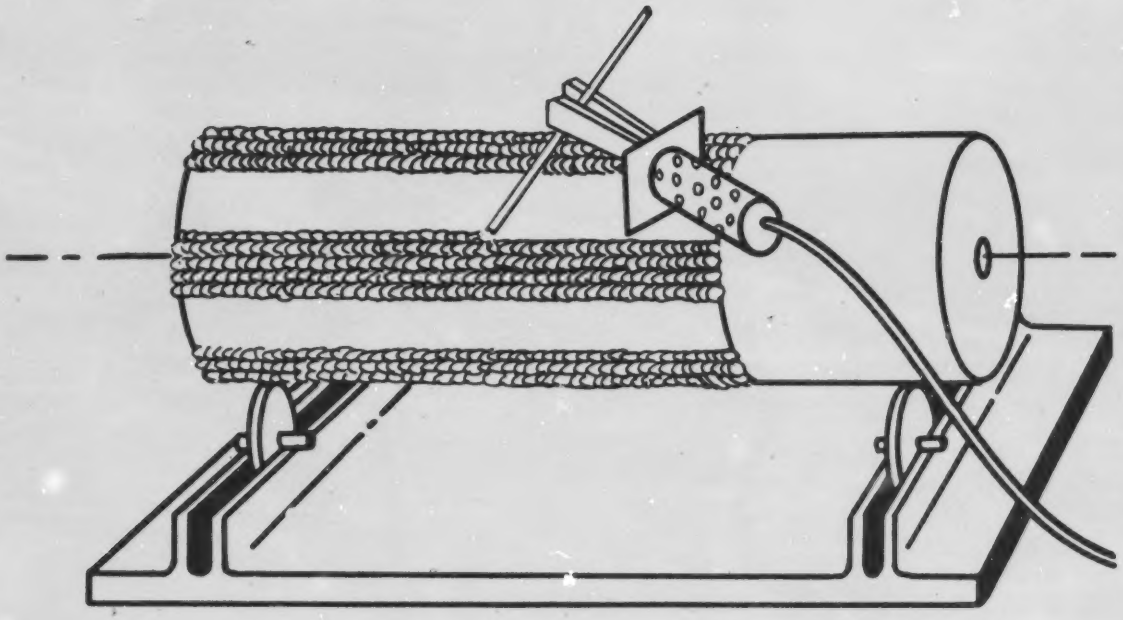


Figure 19. Building Up a Shaft.

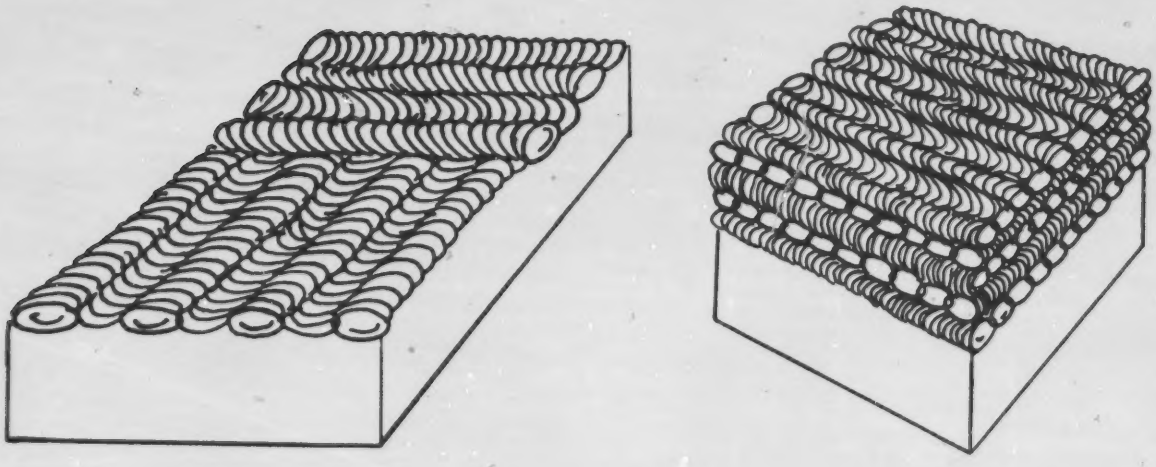


Figure 20. Padding.

overheating with the edges being burned away.

The first full layer of beads is run lengthwise on the part because it allows more time for the part to absorb and distribute the heat from the arc. As each bead is run, be sure there is penetration into the previous bead and the base metal, as shown in figure 17. If you don't get complete fusion, as shown in figure 18, defects such as slag inclusion and voids may develop. These defects can cause additional man-hours and material to be used on the part. All voids and slag inclusions should be removed to avoid uneven wear and premature failure of the part.

Round Surface

The most common round surface requiring buildup is a shaft. It may be from a blower, generator, or from a piece of heavy earth moving equipment. The shaft may range from 1/2" to 8" in diameter and may be from 1' to 20' long. This type of surface is more difficult to build up than a flat surface but if done properly, it can be easy.

The easiest way to build up a shaft is to place it on rollers and run the beads lengthwise as shown in figure 19. The rollers allow for easy handling and running the beads lengthwise allows for heat dissipation. The first bead should be placed slightly above the horizontal center line with each successive bead added above the previous one. Depending upon the thickness of the shaft, it should be rotated 180° after two or three passes to decrease the possibility of warping. By using this procedure, the thickness of the deposit can be closely controlled and the desired diameter can be obtained in one pass.

Precautions

1. Hold a long arc momentarily in starting each pass.

2. Avoid overheating the edges and be sure all craters are filled in.

3. Each bead should be cleaned with a wire brush and a slag hammer.

General Procedures

The following are general procedures to be used when building up worn surfaces.

1. Clean the surface of the metal.

2. Select the proper electrode.

3. Weld successive beads on the plate with each bead overlapping half of the previous bead.

4. Lower the welding current for depositing beads along the edge.

5. Clean each layer of beads.

6. Try different angles of the electrode until you find one that gives good penetration into both the plate and the previous bead.

7. When one layer of beads has been deposited, turn the plate so that the next layer is deposited at right angles to the previous layer, as shown in figure 20.

Caution: Sides and corners must have enough fused metal to be finished square.

QUESTIONS

Note: Answer all questions on a separate sheet of paper. DO NOT WRITE IN THIS STUDY GUIDE.

1. What are the electrode angles recommended for padding in the flat position?

2. What determines penetration?

3. What causes slag inclusions?

4. Why is a round shaft rotated 180° while padding?

5. What is the purpose of "encircling" a plate before padding?

REFERENCES

1. TO 34W4-1-5, Welding Theory and Application.

2. Modern Welding Handbook (Chapter 5) Padding.

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FILLET WELDS IN THE FLAT AND HORIZONTAL POSITIONS

OBJECTIVES

After completing this study guide and classroom instruction, you will apply the techniques used to weld fillets in the flat and horizontal positions.

INTRODUCTION

The fillet weld is a weld bead used to join two pieces of metal when one surface is perpendicular to the other. The fillet weld is used on lap and tee joints. Since the metal pieces of a butt joint are parallel and on the same plane, it is not considered to be a fillet weld.

Each fillet weld has its specific use. The lap joint is used when a quick repair is needed, such as a patch over a hole. It may also be used in the construction of fuel storage tanks when the appearance of the joint or weld is not important.

The tee joint is normally used as a reinforcement to gain additional strength over a long span. An example of this would be shipbuilding. Aircraft fuel tanks may have tee welds as stiffeners. An internal corner weld is a modified tee joint since the requirements of a fillet weld must be met even though it is only welded from one side.

INFORMATION

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TYPES OF JOINTS AND USES

When you are considering which joint to use, you must consider three important factors:

1. The type of load and where it is applied against the weld.

2. The manner in which the load is applied.

3. The cost and appearance of the weld.

A lap joint would fail rather quickly if a sudden or variable load was applied against the weld. A twisting or bending load would also cause it to fail; whereas, it could stand up indefinitely under a tension or compression load. The lap joint is relatively inexpensive to make since there are no joint edges to prepare or special welding techniques other than what you would normally use to ensure a good weld. The metal should overlap 3 to 4 "T" when preparing a lap joint.

The tee joint works very well when a steady bending or impact load is applied. Warpage and distortion is eliminated and it stands up very well to either a compression or tension load. The cost of making this type of joint must be considered because of the expense involved with joint preparation.

The best type of joint to use in order to gain the full strength of the base metal and the highest resistance to any type of applied load is the butt joint. It is also the best when appearance must be considered; however, the cost must be considered due to the amount of time involved in preparation of the joint edges.

At times the choice will be made by your supervisor or a design engineer. Even when this is the case, you are the one that turns out the finished product. Be sure you have the proper machine setting, electrodes, and skill necessary to do the job.

POSITIONS OF WELDS

All welding can be classified according to the position of the plate or welded joint on the plates or sections being welded. There are four general

positions in which welds are required to be made. These are designated as flat, vertical, horizontal, and overhead positions. Fillet or groove welds may be made in all of these positions.

Flat Position Welding

Flat position welding is when the welding is performed from the upper side of the joint and the face of the joint is approximately horizontal.

Horizontal Position of Welding

FILLET WELD. This is the position of welding in which welding is performed on the upper side of an approximately horizontal surface and against an approximately vertical surface.

GROOVE WELD. This is the position of welding wherein the axis of the weld lies in an approximately horizontal plane and the face of the weld lies in an approximately vertical plane.

Note: The axis of a weld is a line through the length of the weld, perpendicular to the cross section at its center of gravity.

Vertical Position of Welding

This is the position of welding wherein the axis of the weld is approximately vertical.

Overhead Position of Welding

This is the position of welding in which welding is performed from the underside of the joint.

WELDING LAP JOINTS

In lap joint, the edges of two sheets are placed one above the other, and the weld applied joining the edge of one sheet to the surface of the other. Lap joints are used in the construction of equipment fabricated from plate and sheet metal. Lap joints are not as efficient in the transmission of load stresses as are butt joints, but certain types of lap joints develop the full strength of the base metal under a tensile pull.

Types of Lap Joints

SINGLE-FILLET LAP JOINT. This type of joint is frequently used, since it requires no machining of the joint edges. This joint is welded from one side only when the design of the part does not permit welding from both sides. The single-fillet lap joint, figure 21, does not develop full base metal strength, but is stronger than a butt weld for some applications. When tubing or frames overlap or telescope together, the lap joint is preferable to the butt joint. If loading is not too severe, this joint is suitable for welding metals of all thicknesses. If fatigue or impact loads are encountered, concentration of stress occur at the edge of the weld. Under tension, the plates may pull out of line, subjecting the root to bending.

DOUBLE-FILLET LAP JOINT. This joint, figure 21, is suitable for much more severe load conditions than can be met by the single-fillet lap joint. When properly made, this joint develops the full strength of the base metal. However, for extremely severe loads, the butt joint is preferred.

JOGGLED LAP JOINT. When you want to use a lap joint but the metal surface must be kept on the same plane, the joggled lap joint, figure 21, is used. This joint gives a more uniform distribution of load stresses than the single or double-lap type. The joint produces a greater strength than the single-fillet lap joint, but is more difficult to prepare for welding.

Weld Specifications

1. The upper leg should equal the base metal in thickness, the lower leg 1-1/2 "T," figure 22. When welds are made on metals of unequal thickness, the specifications are based upon the thickness of the lighter gage sheet.

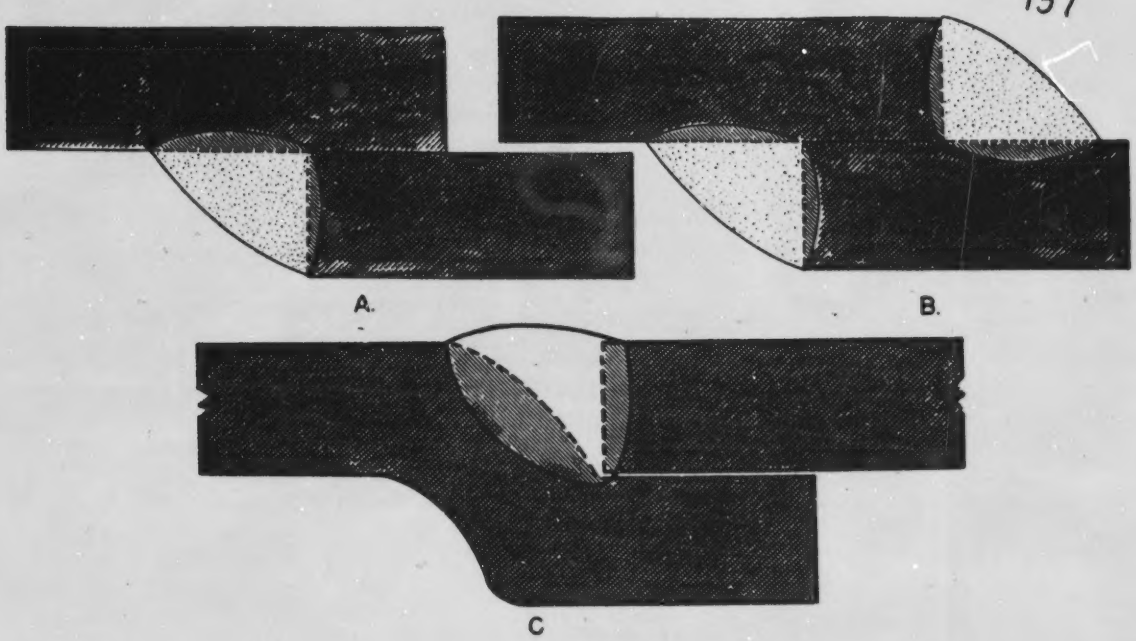


Figure 21. Types of Lap Joints.

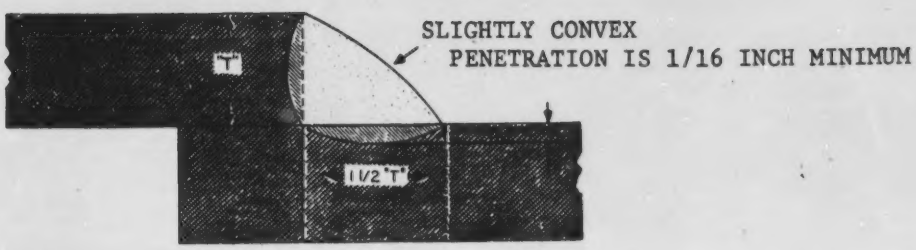


Figure 22. Weld Specifications.

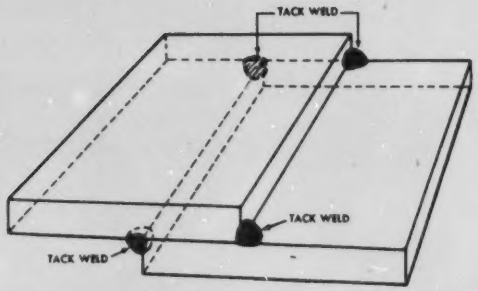


Figure 23. Tack Welding a Lap Joint.

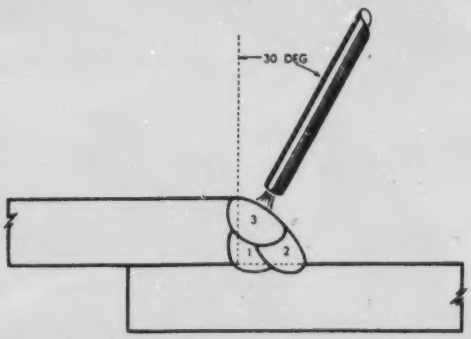


Figure 24. Position of Electrode on Lap Joint.

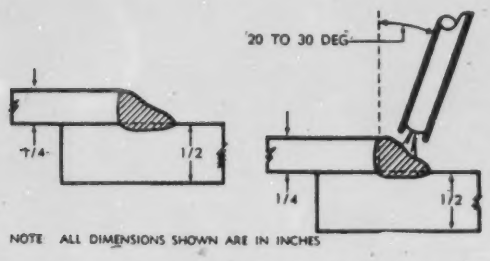


Figure 25. Lap Joints on Plates of Different Thickness.

2. The face should be slightly convex in shape.

3. Penetration should be a minimum of 1/16 inch.

4. The throat thickness should equal the thickness of the base metal.

Welding Technique

1. In making lap joints two overlapping plates are tack-welded in place (figure 23) and a fillet weld in the horizontal position is deposited along the joint.

2. The procedure for making this fillet weld is similar to that used for making fillet welds in tee joints. The electrode should be held so as to form an angle approximately 30° from the vertical and tilted 15° in the direction of welding. The position of the electrode in relation to the plates is shown in figure 24. The weaving motion is the same as that used for tee joints except that the pause at the edge of the top plate is sufficiently long to ensure good fusion and no undercut. Lap joints on 1/2-inch plate or heavier are satisfactorily made by depositing a sequence of string beads, as shown in figure 24.

In making lap joints on plates of different thicknesses, as shown in figure 25, the electrode is held so as to form an angle of between 20° and 30° from the vertical. Care must be taken not to overheat or undercut the thinner plate edge, and the arc must be controlled to wash up the molten metal to the edge of this plate.

WELDING TEE JOINTS IN THE FLAT POSITION

Tee joints may be welded in the flat, horizontal, vertical, or overhead positions. In the flat position, the weld is inclined from 0 to 45 degrees and the rotation of the face is

from 0 to 45 degrees from the 180 degree flat position.

The fillet weld in a tee joint is made by depositing multiple passes of stringer beads or by weaving the electrode to form a wide bead. Stringer beads are generally preferred for fillet welds of maximum strength and ductility because each successive bead tends to refine the grain structure of the previous beads. The sequence of the first three passes of a multiple-pass flat fillet is shown in figure 26. Figure 27 shows several accepted weave motions for depositing a weave bead to cover the stringer beads of a multiple-pass flat fillet weld.

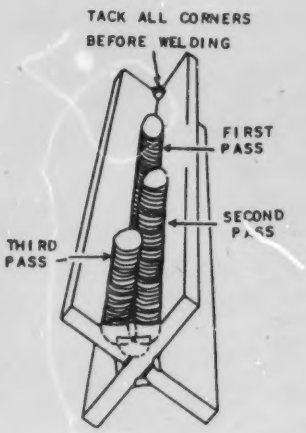


Figure 26. Welding Tee Joint in Flat Position.

Preparation

There are two variations of the tee joint; the square edge tee joint and the beveled edge tee joint. The square edge tee joint (shown in figure 28A) is used on metal up to 3/16" thick and is usually welded from one side. The single bevel (shown in figure 28B) is used on metal from 3/16" to 3/8" thick and is usually welded from one side. The double beveled tee joint (shown in figure 28C) is used on metal over 3/8" thick and is welded from both sides. Whichever edge preparation is used, the edges must be cleaned of all oxide, dirt, etc. to allow a good weld to be produced.

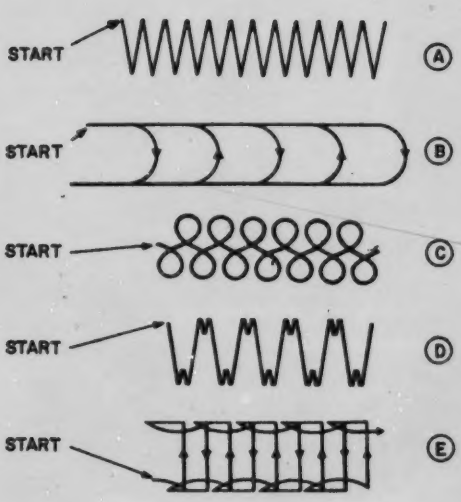


Figure 27. Weave Motions (Flat Position).

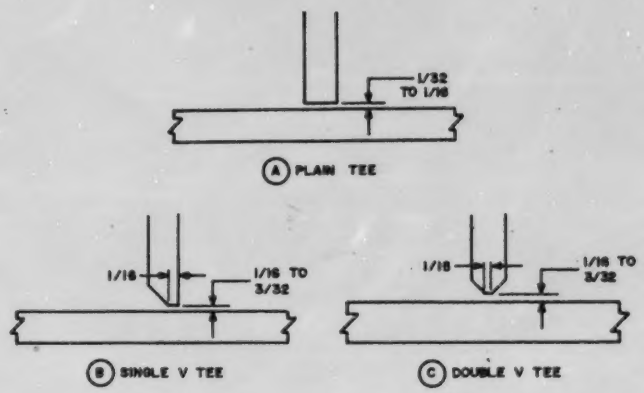
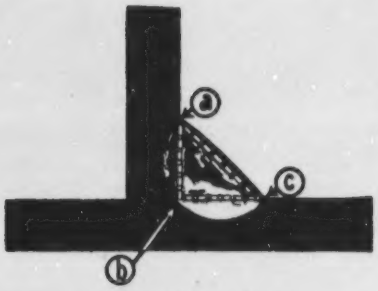


Figure 28. Preparation of Metals for Welding T-Joints.

Specifications

Regardless of whether stringer or weave beads



ABC - Isosceles Right Angle Triangle.
AB = BC AB = 3/8"
Fillet Weld Size - 3/8"

Figure 29. Size of Fillet.

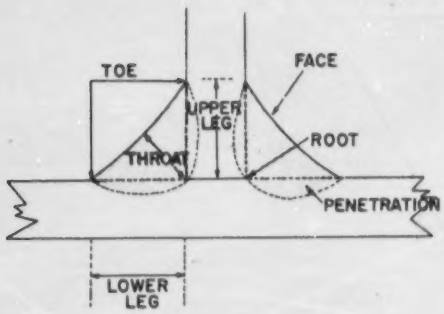


Figure 30. Nomenclature of Tee Joint.

are used in making a tee joint, the size of the weld remains the same. The size of a fillet weld is expressed in terms of the length of the legs of the largest isosceles triangle which can be inscribed in the weld cross section, as shown in figure 29. The common terms used in naming the parts of a tee joint are shown in figure 30. The throat of a tee joint should be equal to the thickness of the base metal (T). The legs should be equal to 1-1/2 times T, and the penetration should be 1/16" minimum.

Weld Faults

UNDERCUT. In the welding of tee joints, undercutting frequently occurs along the toe of the upper leg. This defect is a groove melted in the base metal adjoining the toe of the weld, as shown in figure 31A. The primary causes of this defect are a welding current too high and an improper angle of the electrode

Correcting the current setting, changing the electrode angle, and manipulating the electrode to wash molten metal up to the toe of the vertical leg usually corrects this fault. Figure 31B shows the characteristics of a good tee joint.

OVERLAP. This defect is the result of filler metal overlapping on the base metal without fusing to it, as shown in figure 31A. The angles of the electrode illustrated in figure 32 with the weave illustrated in figure 33 helps to overcome overlapping. Only highly-skilled operators can successfully make large horizontal fillet welds using a weave bead, so that multiple-pass stringer bead fillet welds are most widely recommended for large horizontal fillet welds.

SLAG INCLUSIONS. Nonmetallic inclusions trapped in the weld are called slag inclusions. They are caused by the covering of the electrode being trapped in the molten pool when there is insufficient heat, too long an arc, or an improper angle of the electrode.

Procedure Used to Prevent Faults

1. Clean the surfaces of the metal.

2. Select the proper electrode.

3. Complete the first pass in each joint.

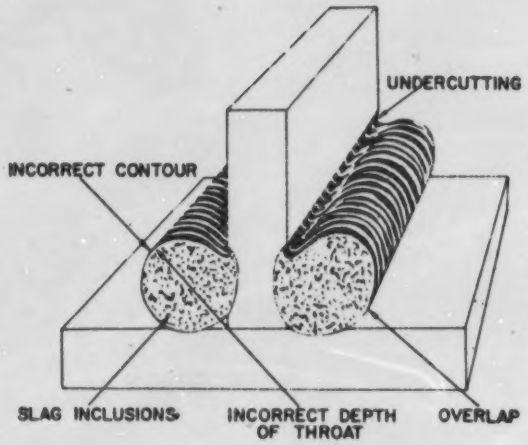


Figure 31A. Characteristics of a Poor Tee Joint.

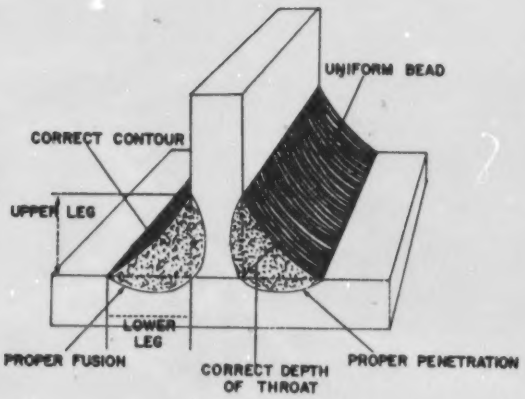


Figure 31B. Characteristics of a Good Tee Joint.

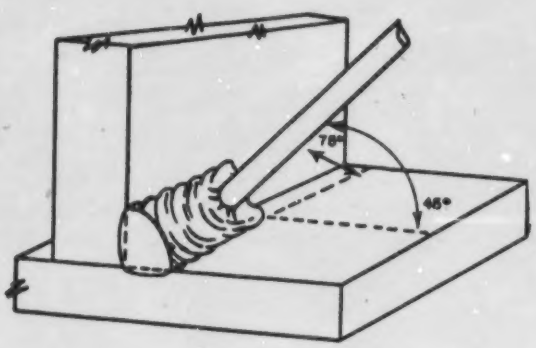


Figure 32. Angle of Electrode.

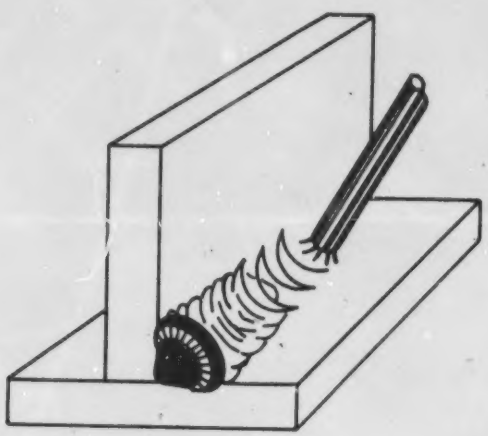


Figure 33. Electrode Weave.

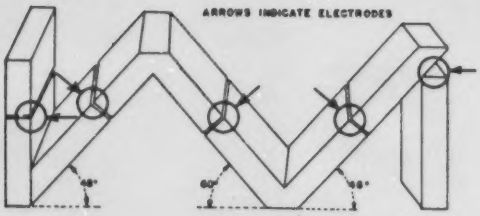


Figure 34. Positions of Horizontal Welds.

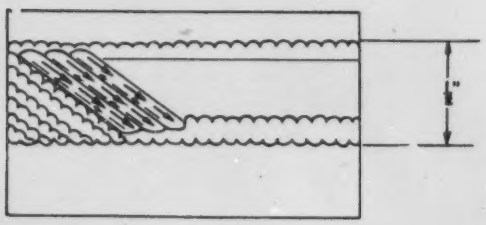


Figure 35. Wide Beads Horizontal Position.

4. Chip off the slag and wirebrush all the welds.

5. Complete each joint by making the welds in the proper order.

WELDING TEE JOINTS IN THE HORIZONTAL POSITION

When the work cannot be positioned for downhand welding, it is referred to as position welding. Position welding is welding that must be done in the position normally occupied by the joint. When the metal parts are inclined more than 45 degrees from horizontal with the line of weld running horizontally as shown in figure 34, it is called a horizontal weld. The weld beads can either be applied as stringer beads or weave beads.

Weave Beads

Weave beads, normally used in all other positions, cannot be used in making horizontal welds. A normal weave is not used because there is no "shelf" of previously deposited metal to hold the molten metal in place. Therefore, in place of a normal weave bead, a series of short diagonal welds are made along the line of the weld. Figure 35 illustrates this method. The upward path is indicated by a dotted line which is a rapid movement of the electrode with very little metal deposit. The main deposit is made on the downward movement as indicated by the dark arrows. A distinct hesitation with a slight backward and forward motion on the top of the weld assures penetration at this point. Each diagonal weld should overlap the preceding weld in order to avoid undercut areas and produce a uniform weld deposit. The tip of the electrode should be tilted upward and directed back toward the weld crater to assist in washing the slag backward and fill the undercut areas.

Stringer Beads

In making fillet welds in horizontal tee joints, the electrode should be held perpendicular to the line of weld, bisecting the angle between the joint edges. When one weld is insufficient to produce the correct fillet size, multiple-pass welds or stringer beads are used. The initial weld or "root bead" is deposited so that the weld metal is equally divided between the upper and lower plate. The cleaning of each weld is necessary before additional welds are placed in the joint. The second weld is made by directing the arc on the edge of the first weld. This permits fusion to take place one-half its width into the first weld and the other half into the lower plate. This same procedure is used on the next pass, fusing the root bead with the edge of the upper plate and

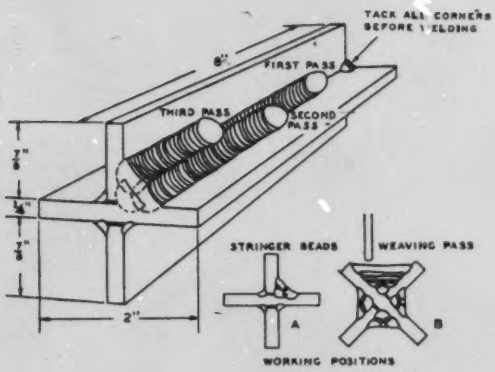


Figure 36. Fillet Weld in Horizontal Position.

the stringer bead. Additional welds may be deposited as required to produce a fillet weld of the proper size. Figure 36 illustrates this technique of depositing a number of stringer beads in tee joints in heavy steel plate.

QUESTIONS

Note: Answer all questions on a separate sheet of paper. DO NOT WRITE IN THIS STUDY GUIDE.

1. What degrees are considered flat welding?

2. What angles are recommended for a horizontal fillet?

3. What edge preparation is necessary for a half inch tee joint?

4. Why is grease and oil removed before welding?

5. How is undercutting eliminated when using a weave bead?

6. Why are stringer beads in a tee joint overlapped half of the prior bead?

7. Where is the initial deposit made when welding tee joints?

8. What is the overlap when setting up a lap joint?

9. Why are tee joints spaced prior to tacking and welding?

10. Where is the second pass directed when welding horizontal tees?

REFERENCES

1. TO 34W4-1-5, Welding Theory and Application.

2. Modern Welding Handbook (Chapter 5, para 17).

Metals Technology Branch
Chanute AFB, Illinois

3ABR53131-SG-305

BUTT JOINTS OF CARBON STEEL PLATE

OBJECTIVES

After completing this study guide and classroom instruction, you will apply the welding techniques in making butt welds of carbon steel plate.

INTRODUCTION

A butt joint is used to join two pieces of metal whose surfaces are in the same plane. Several types of butt joints may be used, depending upon the position and thickness of the metal. When properly made, the butt joint withstands bending, shearing, and twisting loads better than any other joint.

INFORMATION

MANAGEMENT OF DEFENSE ENERGY AND RESOURCES

Due to the conservation of energy and resources, do not write in or mark on any training literature since it will be reused by other classes. Lights will be turned off any time the classroom is vacant for more than 20 minutes. All consumable materials will be used conservatively throughout Block III.

WELDING

In order to meet welding requirements for heavy sections, joint edges must be prepared by beveling the edges of the plates. This joint preparation is necessary to secure complete penetration to the root of the joint. When, due to the thickness of the plates, welds cannot be made by a single weld bead, a series of either stringer or weave beads are used.

Multiple-Pass Beads

This method of depositing weld metal is used when welding thick plates. It is done in order to avoid carrying a large molten pool which may cause slag inclusions or cold shuts in the weld. A large molten pool is difficult to control; therefore, it requires high heat and a slow speed of travel, resulting in excessive melting down of the joint edges.

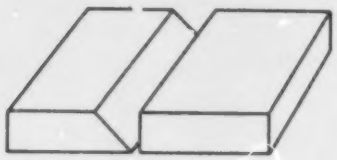
By using multiple-pass welds on heavy butt joints, you can concentrate on getting good penetration at the root of the V in the first pass or layer. On succeeding layers, devote your effort entirely to getting good fusion with the sides of the V and the preceding layer. The final layer is then easily controlled to obtain a good smooth surface.

This method of welding permits the metal deposited in a given layer to be partly or wholly refined and therefore improves the ductility in the succeeding layers. The lower layer of weld metal, often cooling to a black heat, is reheated by the upper layer to a temperature high enough to permit grain refinement, which in effect is a form of heat treatment. The depth of metal affected by this action is dependent upon the penetration of the welding heat. In some classes of work, when this added quality is desired in the top layer of the welded joint, an excess layer of weld metal is deposited on the finished weld and then machined off. The purpose of this bead is simply to supply welding heat to refine the weld metal in the final layer at the surface of the joint.

Joint Preparation

In making various types of butt welds in carbon steel plate, the following examples are typical and should serve as a general guide for welding steel plate of various thicknesses. In addition to the plate thickness, another factor which may influence the method of joint preparation is the type of equipment available for beveling

or grooving. Joint edges can be prepared by flame cutting, shearing, flame grooving, machining, chipping, or grinding.



A SINGLE BEVEL

B DOUBLE BEVEL

Figure 37. Beveled Butt Joint.

The single bevel, shown in figure 37A, is used in welding metals from 1/8" to 3/8" thick. The edge should be beveled to an angle of 30 to 35 degrees. The single bevel is used when one of the plates cannot be beveled due to its shape, location, or fixed position. In this case, the weld is made from one side.

The double bevel, shown in figure 37B, is used on metals over 3/8" thick. The edge is beveled from both sides with each side being beveled to an angle of 30 to 35 degrees. The double bevel may be used when the joining plate cannot be beveled in the same manner and for work that can be welded from both sides. The double V requires approximately one-half as much electrode as the single V butt joint.

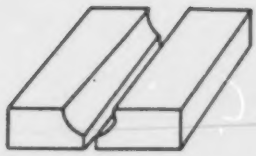
A SINGLE V

B DOUBLE V

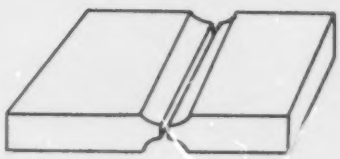
Figure 38. V Butt Joint.

The single V, shown in figure 38A, differs from the single bevel in that the edges of both plates are beveled. The included angle of the bevel should be from 60 to 75 degrees. It is used on the same thickness of metal as the single bevel. The weld is made from one side only. The number of passes required will depend on the thickness of the metal.

The double V, shown in figure 38B, differs from the double bevel by the edges of both plates being beveled instead of just one. The included angle of the double V bevel should be from 60 to 75 degrees and is used on the same thickness of metal as the double bevel. In general, butt joints prepared from both sides permit easier welding, produce less distortion, and ensure better weld metal qualities in heavy sections than joints that are prepared from one side only.



A SINGLE U



B DOUBLE U

Figure 39. U Butt Joint.

The single U, shown in figure 39A, may be used in place of the single or double V for joining plates 1/2" to 3/4" thick and is occasionally used on heavier plates. The U-shaped type of joint is more satisfactory and requires less filler metal than the V type when welding heavy sections or deep grooves. The weld is made from one side except for a single bead which is made last on the opposite side of the U.

The double U, shown in figure 39B, is used for joining heavy plates usually 3/4" and greater. Less weld metal is

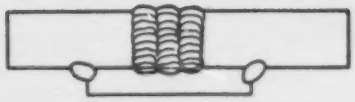


Figure 40. Square Edge Butt Weld With Backing Strip.

required than with the single U and welding is done from both sides.

The square edge butt joint with backup strip, shown in figure 40, is used for joining heavy plate where beveling is not practical. If necessary, the backup strip may be removed by scarfing after completing the joint.

Procedure

The joint edges should be prepared as previously outlined. Depending upon the size of the shoulder at the bottom of the joint edge, spacing should be provided in the exact amount. The parts should be tack welded in place at short intervals along the seam. The slag deposited during tack welding should be removed to prevent its inclusion into the weld. The first bead (root bead) should be made with an electrode small enough in diameter to obtain good penetration and fusion at the base of the joint. A 1/8" or 5/32" electrode is suitable for this purpose.

A long arc is held momentarily in order to obtain penetration at the start of the weld. The top of the electrode should be tilted slightly in the direction of travel. The exact angle depends on the type of electrode used and the current setting. The root bead should be thoroughly cleaned by chipping and wire brushing before additional passes or layers of weld metal are deposited. A 5/32" or 3/16" electrode should be used to make additional passes of filler metal in the joint. Weaving makes it possible to deposit more metal at a single pass in welding in a V on heavy weld without stopping, and at the same time proceeding along the line of weld. Figure 41 illustrates a weaving motion of the electrode which will produce best results in welding heavy butt joints in the flat position. The movement of the electrode is semicircular across the line of weld. A slight hesitation of the electrode at the toes of the weld will aid in preventing undercutting. The number of passes or layers of weld metal will depend upon the thickness of metal being welded; however, a sufficient number in any case is used to build the weld with a series of small stringer or weave beads. The heat input and, therefore the formation of hard zones in the base metal, will be kept to a minimum. Each bead or layer of weld metal will refine the grain in the weld immediately beneath it and will anneal or soften the hardness produced in the base metal by the previous bead.

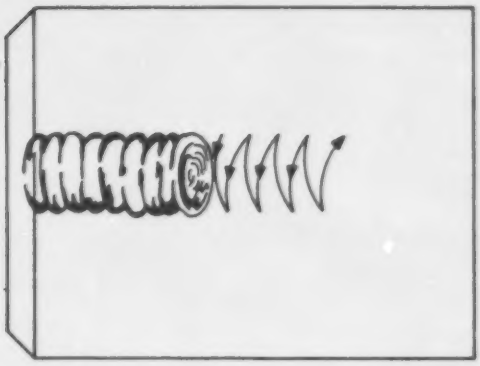


Figure 41. Typical Heavy Weld Weave.

In welding heavy sections that are beveled from both sides, the weave beads should be deposited alternately on one side and then on the other. This reduces the amount of distortion in the weld metal. Thoroughly remove all scale, oxides, and adhering slag before additional metal is deposited. The motion of the electrode should be controlled to make each bead uniform in thickness and to prevent

WELD REQUIREMENTS HEAVY BUTT JOINT OF CARBON STEEL

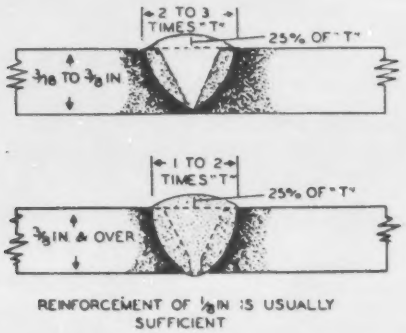


Figure 42. Specifications for Thicker Metals.

undercutting and overlap at the edges of the weld.

The welds shown in figure 42 illustrate the requirements for butt joints on steel plate for thicknesses from 3/16" to 3/8" and over. The width of the fusion zone for heavy plates is governed by the preparation of the joint. When the edges to be welded are beveled, the weld should be approximately 1/8" wider than the included angle of the bevel. The depth of fusion into the beveled edges of the joint should be a minimum of 1/16". Reinforcement height of 1/8" is usually sufficient for heavy plate. The penetration for butt welds must be 100% regardless of the thickness of plate. In the case of double edge preparation, penetration of 50% is obtained from each side to produce the required full base metal penetration.

BEND TEST. The bend test may be used to produce a fracture through the weld so that a cross section of the weld metal is exposed for examination. The specimen is placed in a vise so the jaws will grip the metal just at the seam that has been welded. The projecting portion of the specimen is then bent back toward the weld side until a fracture is produced. This test indicates the soundness of the weld by showing on the fractured surface the extent of the penetration obtained, the presence of oxide or slag inclusions and the degree of porosity.

ETCH TEST. Some joints, such as fillet welds between tubes and sheets of heavy plate welds, cannot be broken to produce a fracture. These joints may be examined by etching. The weld exposed at each cut must then be polished and etched with a solution consisting of equal parts of hydrochloric acid and water, or one part nitric acid to two parts of water. The procedure using either solution is as follows:

1. Remove all saw marks from the surface with a fine mill file.

2. Work out the file marks with coarse-grained emery cloth.

3. Bring the surfaces to a mirror-like finish using successively finer grained emery cloth.

4. Avoid touching the polished surface with the hands or any substance that may leave a film of grease or oil.

5. Apply the acid solution with a brush or swab and allow the piece to stand until all chemical action has ceased.

6. Wash the surfaces with warm water and allow to dry.

7. Examine the surfaces for defects. The depth of fusion and uniformity of grain structure may be readily seen.

General Procedures

The following general procedures will be used when welding butt joints on steel plate.

1. Bevel the edges of the metal.

2. Grind or file the shoulders approximately 3/32" deep.

3. Check the pieces for alignment.

4. Space the pieces approximately 3/32" and tack weld both ends securely.

5. Support the work clear of the surface of the table and weld the first pass, using a 1/8" diameter electrode.

6. Chip off slag and brush clean.

7. Weld the second pass. Weave the electrode to secure the correct width of bead, using a 5/32" diameter electrode.

QUESTIONS

Note: Answer all questions on a separate sheet of paper. DO NOT WRITE IN THIS STUDY GUIDE.

1. What is the reinforcement of a 3/16" butt joint?

2. What is the required penetration of a 1/4" butt joint?

3. What size electrode is used for the root pass on a 1/2" butt joint?

4. Why is a long arc held at the start of a butt joint?

5. What is the reinforcement's width on a 1/4" butt joint?

6. What is the depth of fusion in a 1/4" butt joint?

7. What must be done after tacking and prior to welding a butt joint?

8. What is the angle of bevel on one plate of a single bevel butt joint?

9. Why is spacing required in preparing a butt joint?

10. Draw a picture of the single vee butt joint.

REFERENCES

1. TO 34W4-1-5, Welding Theory and Application.

2. Modern Welding Handbook (Chapter 5, para 17).

Metals Technology Branch
Chanute AFB, Illinois

3ABR53131-SG-306

BUTT JOINTS OF CARBON STEEL SHEET

OBJECTIVES

After completing this study guide and classroom instruction, you will apply the welding techniques in making butt welds of carbon steel sheet.

INTRODUCTION

The butt joint is probably the most difficult joint to weld. The weld specifications must all be met to produce a joint that is as strong, if not stronger, than the base metal. The butt joint also withstands bending and twisting loads better than any other joint.

INFORMATION

MANAGEMENT OF DEFENSE ENERGY AND RESOURCES

Due to the conservation of energy and resources, do not write in or mark on any training literature since it will be reused by other classes. Lights will be turned off any time the classroom is vacant for more than 20 minutes. All consumable materials will be used conservatively throughout Block III.

WELDING

Edges should be deburred and squared in order to meet welding requirements for sheet steel. Further preparation, such as beveling, to secure complete penetration to the root of the joint is unnecessary on metal up to .125" (1/8") of thickness. Proper spacing and current setting are critical to ensure sound welds. A single stringer bead is used for best results. Due to the thickness of the metal, weave beads or multiple stringer beads are not recommended.

Single Stringer Bead

The number of passes or thicknesses of the layer weld metal will depend upon the thickness of metal being welded. On sheet steel .125" or less, one stringer bead will be sufficient using 1/8" electrode. The joint edge should be prepared as previously outlined. Spacing should be tack welded in place at short intervals along the seam. The slag deposited during tack welding should be removed to prevent its inclusion into the weld.

A long arc is held momentarily in order to obtain penetration at the start of the weld. The top of the electrode should be tilted slightly in the direction of travel; the exact amount depends on the type of electrode used and the current setting.

Whenever possible, thin sections should be held and spaced in a fixture to allow for shrinkage along the seams, as shown in figure 43. A properly designed fixture will hold the edges in alignment and minimize the flow of heat into the sheet; thereby reducing the amount of expansion and subsequent contraction. The edges to be welded should be spaced an amount equal to the calculated shrinkage of the weld. The amount of spacing will depend upon the kind of metal being welded. For carbon steel, a space equal to the metal thickness is allowed at the starting end of the joint and 1/4" for each foot of seam length plus the metal thickness at the opposite end.

The welds shown in figure 44 illustrate the requirements for butt joints on steel sheet for thicknesses up to 1/8". The width of the fusion zone for heavy plates is governed by the preparation of the joint. When the edges to be welded are beveled, the weld should be approximately 1/8" wider than the spacing. The depth of fusion into the beveled edges of the joint should be 30% to 50%. Reinforcement

ING DATA

SIZES AND CURRENT RANGES (Amps.)
Electrodes are manufactured in those sizes for which current ranges are given)

1/8" SIZE	5/32" SIZE	3/16" SIZE	7/32" SIZE	1/4" SIZE	5/16" SIZE
75-130	90-175	140-225	200-275	250-325	280-400
75-130	90-175	140-225			
80-130 90-140	120-180 130-200	180-250 200-275	210-280 230-310	250-315 280-350	320-410 350-450
90-135 100-150	120-190 130-210	150-265 165-290	225-300 250-325	250-340 275-375	315-405 350-450
75-120 70-110	90-160 80-145	120-200 110-180	150-260 135-235	180-300 170-270	
90-140 80-125	140-200 125-180	200-260 180-235			
110-160 100-145	150-225 135-200	200-280 180-250	260-340 235-305	315-425 285-380	370-500 330-450
	175-250 160-225	230-350 210-315	300-450 275-410		
80-135 90-150	110-180 120-200	155-250 170-275	225-295 250-325	245-325 275-360	
60-120 55-110	115-150 105-135	160-210 145-190			
130-190 120-180	190-250 180-230	240-300 220-280	300-380 280-360	360-440 330-400	
	190-240 175-215	250-300 230-270	300-380 270-340	350-450 315-405	475-600
115-175 100-160	180-240 160-215	240-300 215-270	300-380 270-340	350-450 315-405	450-600
95-155 115-165	120-200 145-230	160-280 200-310	190-310 240-350	230-360 290-410	375-475 400-500
	180-270 170-240	240-330 210-300	275-410 260-380	360-520 —	

75-130	90-175	140-225		190-325	
		140-225			
75-130	90-175	140-175			
	190-240 175-215	250-300 230-270	275-375 250-320	350-450 330-370	
90-150 110-160	110-200 140-230	160-280 200-310			
95-155 115-165	120-200 145-230	160-280 200-310	190-310 240-350	230-360 290-410	

50-100	75-130	95-165		150-225	
55-95	80-135	115-185		200-275	
55-100	80-140	115-190		200-285	
45-95	80-135	100-165		140-225	
55-100	80-140	120-185		200-275	
55-100	80-140	115-190		200-285	
45-95	80-135	100-165			
50-100	75-130	95-165		150-225	
55-95	80-135	115-185			

50-125	70-170	90-220			
45-125	60-170	85-235		125-360	

80-100					
60-110 65-120	100-135 110-150				

40-150 50-165	75-200 80-220	110-250 120-275		150-375 165-410	
		60-150			145-350
		60-150			145-350
	115-225	200-290		255-375	
		130-170		170-225	
	125-210 135-230	150-260 165-285		200-350 220-385	
65-130					
65-100					
		110-275 125-275		150-400 200-400	

Foldout 1. continued

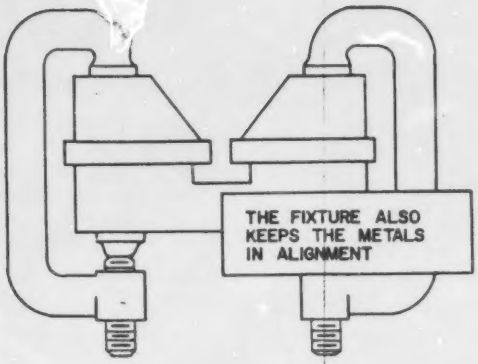


Figure 43. Holding Metals in a Fixture.

WELD REQUIREMENTS SHEET STEEL BUTT JOINT

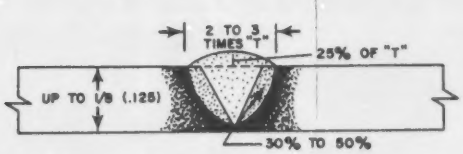


Figure 44. Specifications of Carbon Sheet Steel.

height of 25% "T" is usually sufficient for steel sheet. The penetration for butt welds must be 100% regardless of the thickness of metal.

Light Butt Joint

As the thickness of the metal to be welded decreases, the welding current must be lowered and a smaller electrode used. However, there is a limit to both of these adjustments. The minimum value of welding current with which a stable arc can be maintained depends upon the welding machine. The smallest diameter of electrode that can be used is the one which will not collapse under the amount of welding current required to produce fusion in the base metal. The electrode most suitable for welding light gauge steel sheet in the flat position is classed by the AWS (American Welding Society) as E-6012. This electrode can be used with direct current welding machines and straight polarity or with alternating current machines.

General Procedures

The following are general procedures to be used when welding carbon steel sheets.

1. Clean the edges of any impurities.

2. Match the edges of the sheet.

3. Tack-spacing equal to the metal thickness.

4. Support the work to clear the surface of the table.

5. Make weld using 1/8" diameter electrode.

QUESTIONS

Note: Answer all questions on a separate sheet of paper. DO NOT WRITE IN THIS STUDY GUIDE.

1. How many layers of weld metal are required for metal .125" in thickness?

2. Why is a long arc held at the start of a weld?

3. What is the purpose of spacing in a butt joint of steel sheet?

4. What is the required weld reinforcement for a 1/8" metal butt joint?

5. What is the penetratic requirements for a 1/8" metal butt joint?

REFERENCES

1. TO 34W4-1-5, Welding Theory and Application.

2. Modern Welding Handbook.

ELECTRODE IDENTIFICATION AND OPERA

COATING COLOR	IDENTIFICATION MARKING (E) END	(S) SPOT	(G) GROUP	(L) SPECIAL	AWS CLASS	POLARITY DC (+) = "REVERSE" DC (−) = "STRAIGHT"	5/64" SIZE	3/32" SIZE
MILD STEEL								
White					E6010	DC (+)		
Brick Red					E6010	DC (+)		
Tan		White			E6012	DC (−) AC		55-80 60-90
Gray		White			E6012	DC (−) AC		
White		Blue			E6011	AC DC (+)		40-75 35-70
Dark Tan		Brown		Green	E6013	AC DC (−)	40-75 35-65	65-100 60-90
Gray-Brown	Black	Brown			E7014 E6014	AC DC (−)		
Tan					–	DC (−) AC		
Tan		White		Green	E6012	DC (−) AC		
Brown		Blue			E6011	AC DC (+)		40-90 40-80
Dark Gray	Black	Yellow			E7024 E6024	AC DC (+)		
Red Brown		Silver			E6027	AC DC (±)		
Gray	Black	Yellow		Green	E7024 E6024	AC DC (±)		65-120 60-110
Gray	Black	Orange	Green		E7018 E6018	DC (+) AC		70-100 80-120
Gray-Brown	Black	Black			E7028 E6028	AC DC (+)		
LOW ALLOY, HIGH TENSILE STEEL								
Pink	Blue	White			E7010-A1	DC (+)		50-90
Pink	Blue			Green	E7010-G	DC (+)		
Pink					–	DC (+)		
Dark Red	Blue	Yellow	Silver		E7020-A1	AC DC (±)		
Gray				9018	E9018-G	DC (+) AC		
Gray				11018	E11018-G	DC (+) AC		
STAINLESS STEEL								
Pale Green	Yellow		Black	308-15	E308-15	DC (+)	20-55	30-70
Gray	Yellow		Yellow	308-16	E308-16	DC (+); AC	20-45	30-60
Gray	Brown		Yellow	308L-16	E308L-16	DC (+); AC		30-65
Pale Green	Red		Black	310-15	E310-15	DC (+)		30-70
Gray	Red		Yellow	310-16	E310-16	DC (+); AC		30-65
Gray	Brown	White	Yellow	316L-16	E316L-16	DC (+); AC		30-65
Pale Green	Yellow	Green	Black	318-15	E318-15	DC (+)		30-75
Pale Green	Yellow	Blue	Black	347-15	E347-15	DC (+)	20-55	30-70
Gray	Yellow	Blue	Yellow	347-16	E347-16	DC (+); AC		30-60
BRONZE & ALUMINUM								
Peach	Yellow	Blue	Blue		E-CuSn-C	DC (+)		
Peach					Al-43	DC (+)		20-55
CAST IRON								
Light Tan	Orange				ESt	DC (+); AC		
Black	Orange	Blue	White		ENi	DC (±) AC		
HARDSURFACING								
Black						DC (±) AC		
Slate	Yellow					DC (+); AC		
Slate	Pink					DC (+); AC		
Gray						DC (±); AC		
Bare Wire						DC (+)		
Dark Gray	Orange	Red				DC (±) AC		
Slate						DC (−); AC		40-85
Gray						DC (+)		
Dark Gray						DC (+) AC		

Foldout 1. Color Coding on Common Electrodes.

153

PREPARE THE MAN

STUDY GUIDE 3ABR53131-SG-400

Technical Training

Metals Processing Specialist

BLOCK IV
SPECIAL METALIC ARC AND RESISTANCE
WELDING APPLICATIONS

13-6

3 September 1975

CHANUTE TECHNICAL TRAINING CENTER (ATC)

This supersedes 3ABR53230-SG-400, 8 January 1973.
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Metal & NDI Branch
Chanute AFB, Illinois

3ABR53131-SG-401

FILLET WELDS IN THE VERTICAL POSITION

OBJECTIVES

After completing this study guide and classroom instruction, you will apply the techniques and procedures required for welding vertical fillet joints.

INTRODUCTION

Making fillet welds in the vertical position is one of the most difficult welding tasks you will encounter. Normally, more stringer beads are required to meet the joint requirements because of the need to run smaller beads due to the effects of gravity and surface tension. These factors can be overcome only by using smaller electrodes and shorter arc lengths. The skill of the operator is the primary factor in selecting electrode sizes and in determining arc lengths. Your skill as a welder will be determined by the amount of performance you do on the vertical fillet joint.

INFORMATION

MANAGEMENT OF DEFENSE ENERGY RESOURCES

Due to the conservation of energy resources, do not write in or mark on any training literature since it will be reused by other classes. Lights will be turned off any time the classroom is vacant for more than 20 minutes. All consumable materials will be used conservatively throughout Block IV.

VERTICAL FILLET WELDS

Welding in the vertical position is much more difficult than welding in the flat position. The force of gravity acting on the molten globules passing across the arc tends to deflect them from the crater. The operator is forced to hold a short arc and to manipulate the electrode in order to control the size of the molten pool. The strongest force propelling the globules across the arc is exerted by the gas produced from the electrode coating. This gas expands at a rapid rate, forcing the metal across the gap.

The fillet welded tee joint is commonly used in building and naval construction and is often made in the vertical position. It requires much practice to make consistently good welds in the vertical position. Once this skill is acquired, you will be equipped to make welds in practically any position. Many commercial businesses classify operators in two divisions: one qualified to do work in the flat position only, whereas the other is qualified to do work in all positions.

Lap joints which must be welded in the vertical position, expecially those found in the field, are often found in steel structures fabricated by welding. One reason for using lap joints is that they do not ordinarily require the close tolerances and fitups that butt joints do.

Stringer Beads

The correct position and manipulation of the electrode for welding upward in the vertical position is shown in figure 1. The electrode is held perpendicular to the plates laterally. It is also inclined down about 5 degrees from the horizontal plane, so that the tip of the electrode points slightly upward and away from the crater.

The weld is started by directing the end of the electrode down, as shown in figure 1. This permits the deposited metal to form a shelf. After building up the shelf, the angle of the electrode is changed with the end directed upward. As the weld progresses, the tip of the electrode is momentarily moved upward ahead of the pool of molten metal long enough to permit the deposit to solidify. This is repeated along the line of weld to the top of the plate.

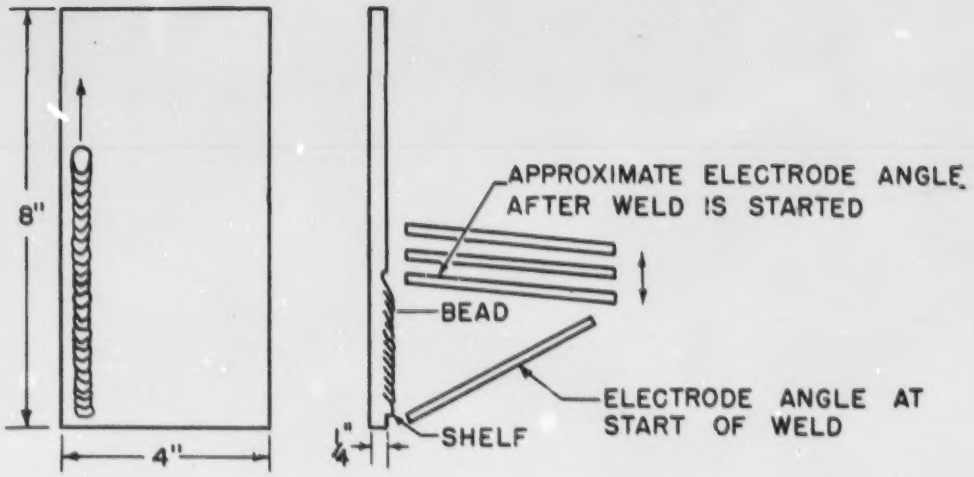

Figure 1. Technique for Welding Upward in the Vertical Position.

A somewhat shorter arc length is required to control the size of the molten pool. The arc is never broken throughout the movement of the electrode. The end of the electrode is moved from the crater just long enough to permit the deposited metal to solidify and form a shelf upon which additional metal is deposited. The timing of this movement may vary since some operators work faster and use higher current values than others. Actual effective deposition of metal should take place only during the time in which the electrode is in position at the downward end of the movement.

Weave Beads

Use a slight weaving motion with the electrode when you want welds that are wider than those produced by the stringer bead technique. You should use a slightly larger electrode with higher welding current to produce the wider weld. A 3/16" diameter electrode is the maximum practical size for vertical welding.

An example of a typical weave in the vertical position is shown in figure 2. The electrode is moved with a slight side to side motion in the crater during the deposition of weld metal. This is followed by an upward movement of the electrode momentarily to allow the deposited metal to solidify. This procedure eliminates the highly crowned bead which may result when the weaving motion is not used. Use a series of stringer beads when larger maximum strength welds are required.

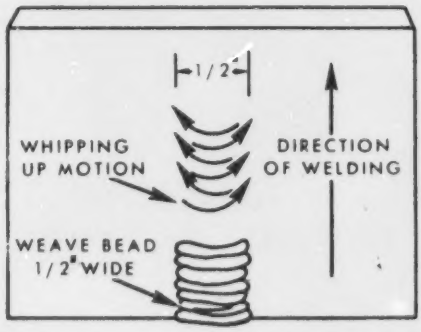

Figure 2. Vertical Weave Bead, Welding Up.

When metallic arc welding, the preferred direction of welding heavy metals is from the bottom upward. However, considerable welding on thin metal is done from the top down. Welding downward on metals in the vertical position reduces the possibility of burn-through. A higher degree of skill is required when using this procedure because of the tendency of slag to trap in the weld.

Tee Joints

The number of welds required to make a vertical tee weld depends on the thickness of the metal being welded. Where more than one layer is required to meet weld specifications, either the stringer bead, shown in figure 3, or the weave bead, shown in figure 4, can be used. A combination of the two can also be used. In either case, the first pass is made in the root of the joint to obtain adequate penetration into the root of the weld. If additional layers are to be stringer beads then each added layer of weld metal requires an additional bead. Each weld is fused into the preceding weld by holding the center of the crater at the edge of the last weld. To avoid trapping slag, clean each weld thoroughly by chipping off the slag and then wirebrushing it.

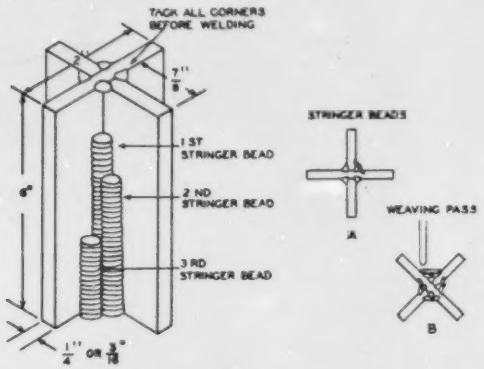

Figure 3. Stringer Beads, Vertical Position.

Weave beads can be made by weaving the electrode, as shown in figure 5. After the root bead has been completed and thoroughly cleaned of all slag, the weave is started by building a shelf then moving the electrode laterally to the desired width of the bead. The electrode is held perpendicular to the plate and moved from side to side. A slight hestitation at the end of the weave results in good fusion without undercutting the plate at the edge of the weld. If the weld metal should overheat, the electrode may be raised from the crater at short rapid intervals without breaking the arc. This allows the molten metal to solidify without running down; however, the electrode should be returned to the weld crater immediately to maintain the desired size of the fillet weld. To eliminate a crater at the end of the weld, break the arc momentarily to allow the weld metal to solidify. This reduces the possibility of overheating and allows the end of the bead to build up to the required specifications.

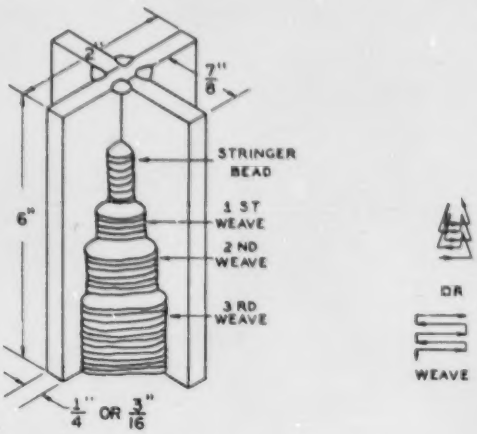

Figure 4. Vertical Tee Joint.

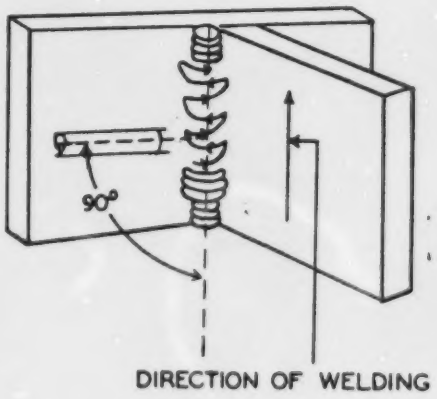

Figure 5. Weaving Motion, Vertical Position.

Lap Joints

When welding lap joints in the vertical position, the electrode should be manipulated as shown in figure 6. Holding the electrode approximately

perpendicular to the plates, start the arc and deposit the weld metal to form a shelf. Move the arc up and away from the molten pool until the molten metal has solidified. Continuous depositing of metal without using this movement causes molten metal to run over the shelf and down the weld. A slight hesitation of the electrode at the bottom of the "J" with the arc directed mainly upon the lower plate aids in penetration and reduces the possibility of overlapping and undercutting.

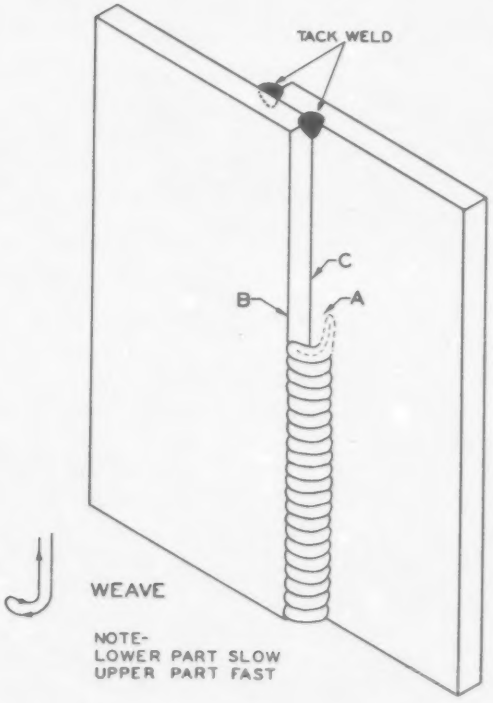

Figure 6. Vertical Lap Joint.

When you weld lap joints of plate up to 1/4" thick, one pass on each side of the weld is normally sufficient to develop the full strength of the base metal. If the metal is thicker than 1/2", a series of stringer beads may be needed, as shown in figure 7. The final pass can be made by weaving the electrode as shown in figure 8. This procedure is necessary when the weld specification cannot be met by a single weld.

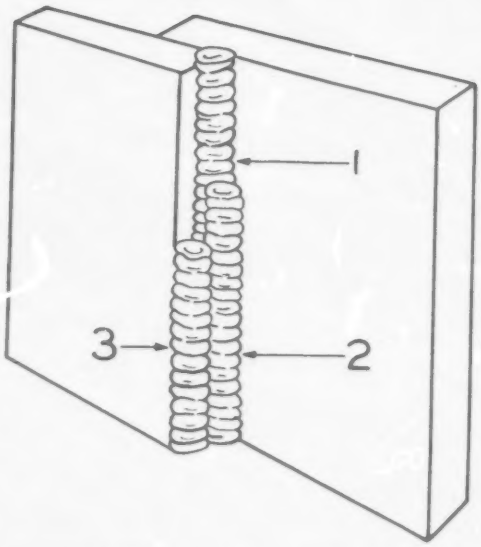

Figure 7. Stringer Beads Vertical Lap Joint.

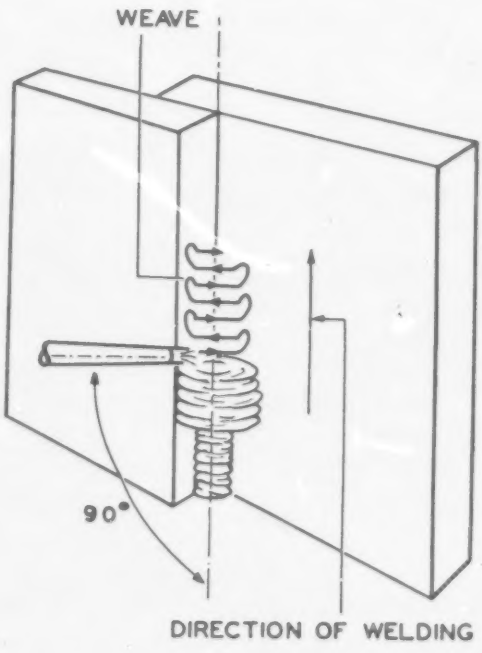

Figure 8. Weaving Motion Vertical Position.

Making satisfactory welds on lap joints is more difficult than making welds on tee joints in the vertical position. This is due mainly to the overlapping edge of the top plate on lap joints. The overlapping edge of the joint is easily overheated if the proper manipulation of the electrode is not used. This causes undercutting at the upper edge of the weld and possible overlap on the lower edge of the weld.

Electrodes

The electrodes used for vertical welding have lighter coatings than the type used for flat position welding. They are designed to allow the weld metal and slag to solidify quickly. This type of electrode is used on reverse polarity. Penetration is secured easily since the greatest amount of heat is at the positive side of the welding circuit (the tip of the electrode). This is an aid to a position in which penetration is otherwise more difficult to obtain. The electrodes are classified under American Welding Society Specifications as AWS 6010 and in AF supply catalogs as Class B.

Current Settings

When using coated electrodes in the vertical position, use smaller electrodes and lower current settings as compared to flat position welding. This helps to maintain a small pool of molten metal; thus permitting surface tension to overcome the force of gravity. The current settings recommended by the electrode manufacturer serve as a guide in making initial settings for a given electrode size.

Joint Preparation and Weld Specifications

The joint preparation and weld specifications for welding in the vertical position are the same as for welding in the flat position. It may, however, be necessary in vertical welding, to make a number of passes for a joint which would require only one pass in the flat position.

Procedures for Welding of Tee Joints

1. Clean the surfaces to be welded.

2. Set up the work, tack weld it securely, and support the work firmly so that it will not fall off the table.

3. Complete the first pass in each joint, being careful to acquire adequate penetration at the root.

4. Complete each side with two additional stringer beads.

5. Weave a pass over the preceding beads in each joint.

6. Continue the weaving passes until all the joints are filled.

Procedures for Welding of Lap Joints

1. Clean the surfaces to be welded.

2. Set up the work and tack weld the top and bottom.

3. Start the weld at the bottom of the joint. Weave the electrode in the manner illustrated in figure 6, making the upper part of the J rapidly and the lower part more slowly. This is required since it is desired to deposit the weld metal only during this part of the movement.

4. Try different electrode angles and rod manipulations until the best one is found.

5. Weld the joint on the reverse side.

QUESTIONS

Note: Answer all the questions on a separate sheet of paper. DO NOT WRITE IN THIS STUDY GUIDE.

1. When are multiple passes used on lap welds?

2. Why is the electrode moved vertically away from the crater in making a "J" weave?

3. What is the main purpose of the root bead in a vertical weld?

4. What determines the number of passes required for tee joints?

5. Can a vertical weld be made with the torch moving downward?

6. Why must the electrode be manipulated when welding lap joints?

7. Where should most of the arc's heat be directed in vertical welding?

8. What type of electrode is suitable for vertical welding?

9. Why is a vertical lap joint more difficult to weld than a vertical tee joint?

10. Why is it necessary to assure good fusion at the root of a weld?

REFERENCES

TO 34W4-1-5, Welding Theory and Application, Modern Welding Handbook (Chapter 5).

Metal & NDI Branch
Chanute AFB, Illinois

FILLET WELDS IN THE OVERHEAD POSITION

OBJECTIVES

After completing this study guide and classroom instruction, you will apply the techniques and procedures required for welding overhead fillet joints.

INTRODUCTION

The overhead position of welding is one in which filler metal is deposited from the underside of the joint and the face of the weld is approximately horizontal. This is probably the most difficult of all the welding positions.

INFORMATION

MANAGEMENT OF DEFENSE ENERGY RESOURCES

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OVERHEAD WELDING

In the erection of structures and equipment, and especially in repair work, it is often necessary to weld in the overhead position. Fortunately, there are forces present in the electric arc powerful enough to overcome the force of gravity and make it possible to deposit metal overhead One of the most effective of these forces is the propelling power of the gases formed by the combustion of the electrode coating. These gases are expanded at a tremendous rate due to the heat of the arc.

Depending on arc lengths, the transfer of metal in the overhead position is accomplished in different ways. An overhead deposit made while holding a long arc is relatively small and due only to condensation of vaporized metal. In the case of the short arc, there is a globular growth until contact is made with the liquified plate or surface of the deposit, as shown in figure 9. Here the forces of adhesion and surface tension at the plate overcome the combined forces of gravity, cohesion, and surface tension holding the globule to the electrode tip. The forces acting against the depositing of molten metal may be overcome by using a small diameter electrode and holding a shorter arc. Heating the joint locally is also helpful in starting an effective metal deposit. This can be accomplished by holding a long arc at the start of the weld. It is often desirable on heavy plate to burn or waste 2 to 3 inches of the electrode in heating the joint.

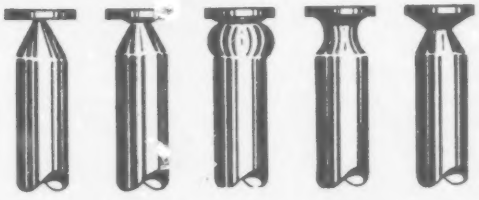

Figure 9. Theory of Overhead Arc Deposits.

Electrodes

Only those electrodes designed for overhead welding should be used. Welding with large diameter electrodes is difficult. The 3/16" diameter electrode is the maximum practical size to be used for overhead welding. The amount of welding current should be carefully adjusted so that a short arc length can be held. Only a slight amount of electrode movement is necessary if the current adjustment and electrode angle is correct.

Polarity

Reverse polarity is used when using a direct current arc welding machine.

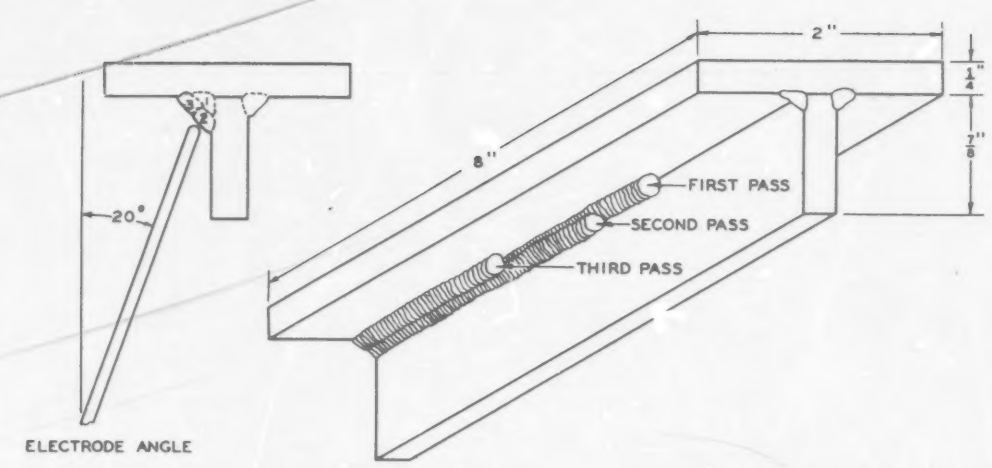

Figure 10. Tee Joint Overhead.

Penetration is more easily obtained since the greatest amount of heat is at the positive terminal of the welding circuit.

Current Settings

The selection of welding current depends on the size of the electrode, the thickness of the plate being welded, the position of welding, and the welder's skill. For overhead position welding, lower current values must be used. In general, the proper current settings are obtained from experience and should be adjusted to fulfill the requirements of the particular welding operation. Data published by the manufacturer should be used only as a guide since many factors affect the current requirements.

Welding Technique

When making fillet welds in the overhead position, a short arc should be held and there should be no weaving of the electrode. The electrode should be held approximately 20 degrees to the vertical plate and moved uniformly in the direction of the welding, as shown in figure 10. The arc motion should be controlled to secure a good penetration to the root of the weld and good fusion with the sidewalls of the vertical and horizontal plates. If the molten metal becomes too fluid and tends to sag, the electrode should be moved away quickly from the crater to lengthen the arc and allow the metal to solidify. The electrode should then be returned immediately to the crater and the weld continued.

When welding heavy plate in the overhead position, several passes or beads are required to make the joint. The order in which these beads are added to the joint is shown in figure 10. The first pass or bead is a stringer bead with no weaving motion of the electrode. The second and third passes are made with a very slight circular motion of the end of the electrode while the top of the electrode is tilted about 15 degrees in the direction of welding. This motion permits greater control and better distribution of the weld metal being deposited. All slag and oxides should be removed from the surface of each stringer bead by chipping or wire brushing before additional beads are deposited in the joint.

Procedures

The following are general procedures to be used when making overhead welds.

1. Clean the metal to be welded.

2. Set up the fixture in the manner described by your instructor. Make sure that the work is securely fastened to the fixture.

3. Attach the work to the fixture in the overhead position.

4. Strike an arc, then hold a long arc until two or three globules fall to the floor, and then shorten the arc to the correct length.

5. Complete the root bead, trying various angles of the electrode until the best one is found.

6. Continue laying stringer beads until the weld is complete. Chip off all slag after each pass.

QUESTIONS

Note: Answer all questions on a separate sheet of paper. DO NOT WRITE IN THIS STUDY GUIDE.

1. What is the cause of slag inclusions in position welding?

2. How may the forces acting against the deposit of metal in the overhead position be overcome?

3. What diameter electrodes are usually used for overhead welding?

4. What are the causes of undercutting on overhead welds?

5. Why do you use a short arc in overhead welding?

6. What is the principal difficulty in welding in the overhead position?

7. Which forces in the arc aid in overhead welding?

8. What force hinders overhead we welding?

9. When direct current is used for welding in the overhead position? What polarity is used?

10. What type of electrode should you use in welding in the overhead position?

REFERENCES

TO 34W4-1-5, Welding Theory and Application, Modern Welding Handbook.

Metal & NDI Branch
Chanute AFB, Illinois

PIPE JOINTS

OBJECTIVES

After completing this study guide and classroom instruction, you will apply the techniques and procedures required to perform metallic arc welding of pipe joints.

INTRODUCTION

A tubular section is the most effecient where a large amount of torsion is involved, It is for this reason that aircraft engine mounts and landing gears are constructed chiefly of tubular shapes. In the construction field, pipe is being used extensively for structures such as frames, platforms, and fixtures. The petroleum industry uses pipe for transporting liquids and gases, and the equipment necessary for production of these fuels. Welding has made available the use of tubular sections for these purposes since joints are made directly to other members without the use of a mechanical connecting member.

INFORMATION

MANAGEMENT OF DEFENSE ENERGY RESOURCES

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TYPES OF JOINTS

The advantages of arc welded piping systems are: (1) permanently tight connections of great strength and rigidity, (2) resistance to flow due to elimination of projections inside the pipe, (3) a pleasing appearance, (4) easy and cheap application of insulation, (5) simplification of design, and (6) elimination of many fittings required by mechanically connected systems.

This freedom of design with tubular steel members is just one way welding makes savings possible that cannot be obtained by any other method of fabrication or construction.

Butt Joint

The most common type of joint used in the fabrication of welded pipe systems is the butt joint. It is the most satisfactory from the standpoint of stress distribution. When the wall thickness of the pipe is 3/16" or greater, the ends of the pipe are beveled to an angle of 20 to 37-1/2 degrees to within 1/16" of the inside wall of the pipe, as shown in figure 11. The oxyacetylene cutting torch is used to bevel heavy walled pipe, whereas, thin walled pipe can be beveled by using a pedestal grinder.

A backing ring is used when joining large diameter pipe which is subjected to severe service conditions. This is a ring shaped strap which is fitted to the inside surface of the pipe at a joint prior to welding. It may be either a plain flat strap rolled to fit the inside diameter of the pipe or a forged or pressed shape with or without projections which space the two pipe ends the proper distance apart, as shown in figure 12. Its function is to assist the welder in securing complete penetration to the inside surface of the pipe without burning through and to prevent globules of spattered weld metal and slag from entering the pipe. Backing rings help align the pipe ends but are not normally used in shop fabrication. They are removed after the welding has been completed when internal cleaning is to be done.

Butt joints should be reinforced with weld metal in excess of the net throat dimension by at least 1/16". The reinforcement should be gradually increased in thickness from the edge to the center. Avoid excessive reinforcement because it tends to introduce undesirable stress concentrations.

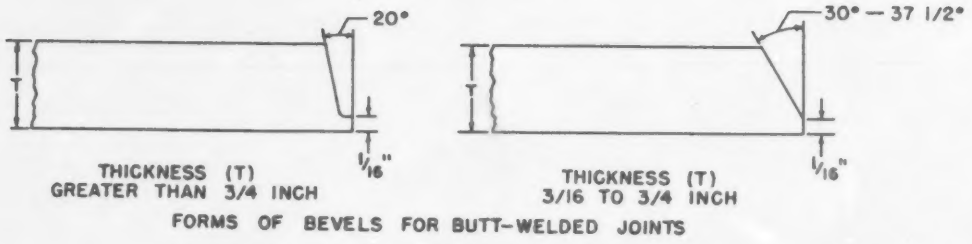

Figure 11. Forms of Bevels for Butt-Welded Joints.

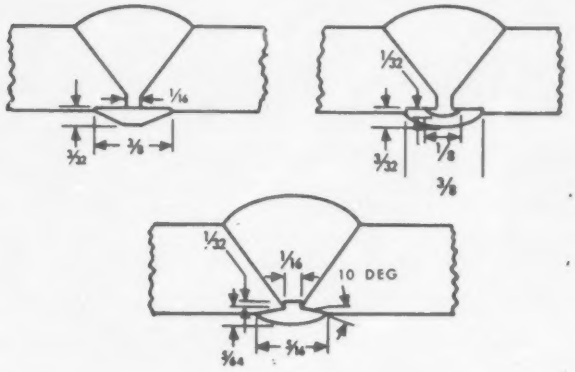

Figure 12. Types of Backing Rings.

Fillet Joint

The general application for the fillet joint in pipe is the intersection joint such as the tee, ell, or wye. Joining pipe where one member forms an angle to another, presents the problem of either preparing both ends of the pipe to form the joint or fitting a single pipe to join another at an angle. Depending on the time factor involved, the joint prepration can either be done by guessing at the proper angle of the cut or by making and using a template.

The materials necessary for making patterns consist of a straight edge, triangle, compass, rule, a piece of heavy paper, and a pencil. In laying out a pattern for a 90-degree bend, first lay out the joint actual size, letting the lines represent the outside diameter of the pipe, as shown in figure 13. Next, inscribe a circle and divide it into 12 equal parts. Number the parts beginning with zero. Extend these joints over line AA and number the intersections to correspond with the points of the circle, as shown in figure 14. Draw line BB at a right angle to the diameter, starting it three inches from the corner. This completes the preliminary details prior to making the actual pattern.

Proceed to lay off line CC which represents the circumference of the circle, as shown in figure 15. Divide this line into as many equal parts as the circle was divided into and number them beginning at the left with zero. At each division, draw a line at a right angle to CC. Starting at 0 on the vertical line, lay off a length equal to B-0; on line 1, lay off length B-1; on line 2, B-2; etc. until B-12 is laid off, which is equal to B-0. Now, join the extremities of these lines and the result should be the curve AA which corresponds

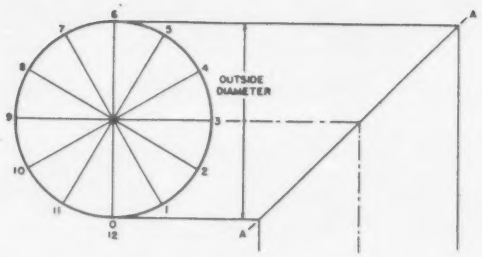

Figure 13. Laying Out a Pattern a 90° Bend (First Step).

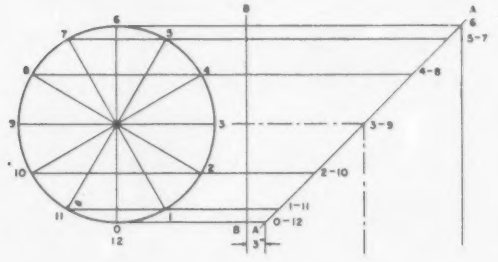

Figure 14. Laying Out a Pattern a 90° Bend (Second Step).

to the line A'A' in figure 15. The pattern is cut out by cutting along the edges CA', A'A', A'C, CC.

The pattern is then wrapped around the pipe. Hold it in position with one hand and mark an outline on the pipe with soapstone following the line A'A'. This is the cutting edge. Cutting the two pieces of pipe on line A'A' and butting them together results in a 90-degree bend which should require no trimming other than beveling of the edges.

This procedure can be applied to any pipe joint. If a pattern for a tee is to be made, the joint is laid out as shown in figure 16. The pattern is wrapped around the outlet of the tee so that the circle is inscribed in the outlet and not in the run.

The difference between this pattern and the pattern for the ell is that the cutting line AA is half a circle instead of a straight line. After the outlet is cut along the edge A'A' on the pattern, it is placed in position on the run and the outline marked and cut. The outlet serves as a pattern to cut the opening in the run. This procedure may also be used in laying out patterns for a pipe elbow as shown in figure 17.

WELDING PROCEDURES

Cleaning

The welding faces and the adjoining pipe surfaces should be cleaned back at least 1/4" from the welding groove. All rust, paint, scale, oil, or grease should be removed by either the chemical or mechanical method. They make it difficult, if not impossible, to secure penetration and fusion to the base metal and a sound weld deposit.

Alignment

The pipe must be carefully lined up before welding. If the two pieces to be joined have the same internal diameter, regardless of wall thickness, backing rings may be used to bring the bore of the two pieces into alignment. When backing rings are not used, the two pipes or fitting ends are often secured in a fixed position by an external clamp. They can also be secured by positioning in a channel or section of angle iron large enough to permit the ends to fall into proper line, as shown in figure 18. Where the pipes meet at an angle, a suitable fixture may be constructed if a number of such joints warrant its construction. Proper alignment for angular members can be closely maintained by predetermined allowances for contraction of the weld, along with proper welding procedures, thus eliminating the need for a fixture.

Tacking

After the joint is aligned, tack weld at regular intervals prior to actual welding. This maintains the joint alignment and permits removal of any external fastenings which may have been used for this purpose and which would interfere with the complete welding of the joint. Tack welding also permits handling the pipe after setting up and

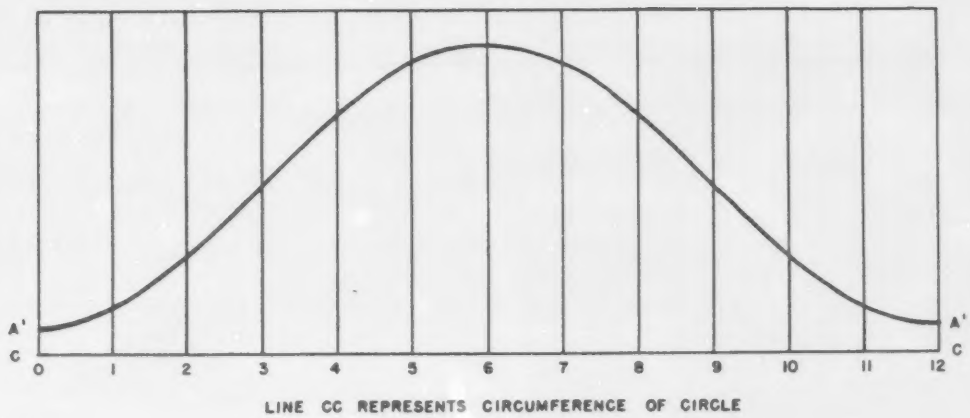

Figure 15. Pattern for 90° Bend.

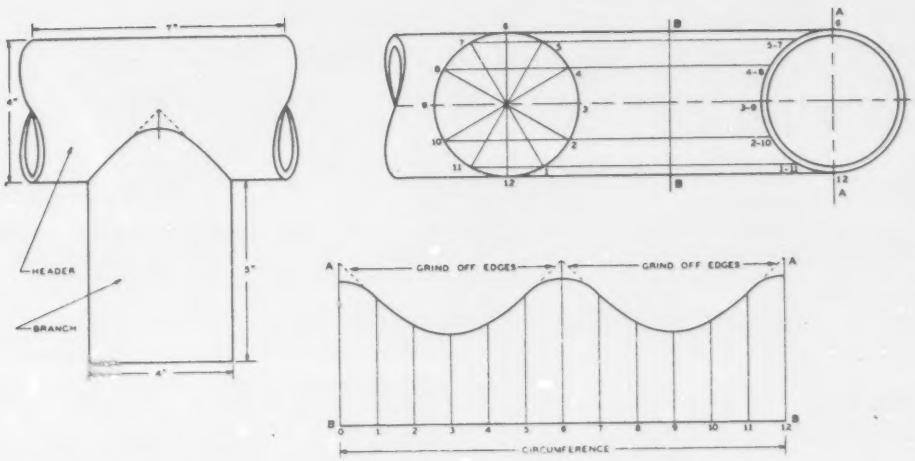

Figure 16. Laying Out the Pattern for a Tee.

before welding. As a rule, the length of tack welds in arc welding should be two to three times the thickness of the parts joined. Tack welds should be thoroughly fused into the main weld.

Welding Technique

Pipe welding involves no new principles of welding. The main difference is that either the position of the work or the welder must be constantly changed due to the circular form.

There is no specific direction for welding pipe in a fixed position. The preferred direction is usually from the bottom upward; however, considerable welding, especially of thin or medium wall thickness pipe, is done in the opposite direction. Ordinarily, more metal per layer is deposited in welding upward, and the requirement of having the layers thin enough to undergo

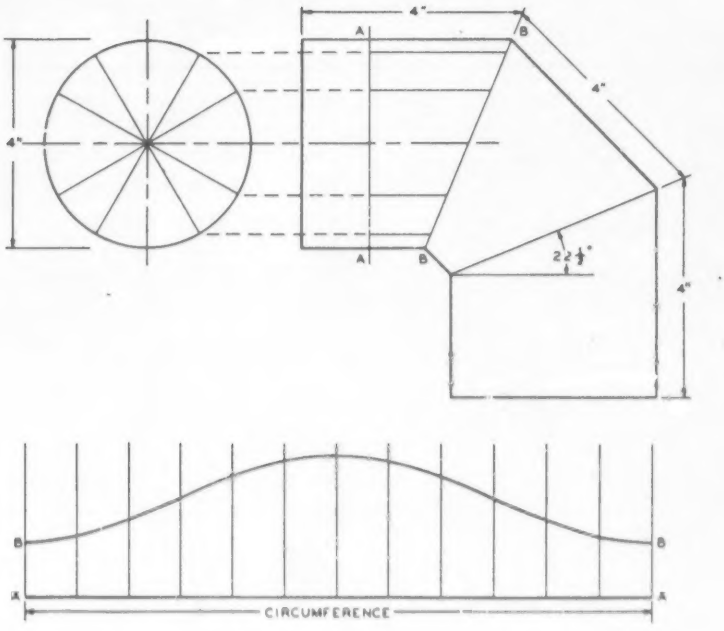

Figure 17. Layout of Welded Angle Joint of Heavy Pipe Construction.

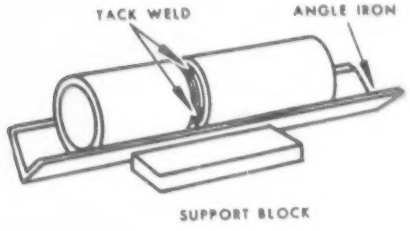

Figure 18. Angle Iron Serving as Fixture for Small Diameter Pipe.

complete grain refinement must be considered. Downward welding requires a higher degree of skill to secure adequate fusion with the side walls and to avoid trapping the slag.

The number of passes required to make a pipe weld varies with wall thickness of the pipe and the position of the pipe when it is welded. When the work can be rolled or when the pipe is in a fixed horizontal position, a layer of metal is deposited across the full width of the welding groove during each pass. When the pipe is in a fixed vertical position, the metal is deposited in a series of stringer beads. Regardless of the position of the pipe, there is usually one layer or pass for each 1/8" of wall thickness.

Each layer of weld metal should be thoroughly cleaned before depositing the next layer. Chip with a slag hammer and wire brush it to remove all slag deposits.

Weld Repair

When a weld is to be repaired, the defect should be removed by chipping, machining, flame gouging, or flame cutting. After removing the defect, clean and shape the repair area so that a sound weld deposit can be obtained.

Procedure

The following are general procedures to be used when making pipe welds.

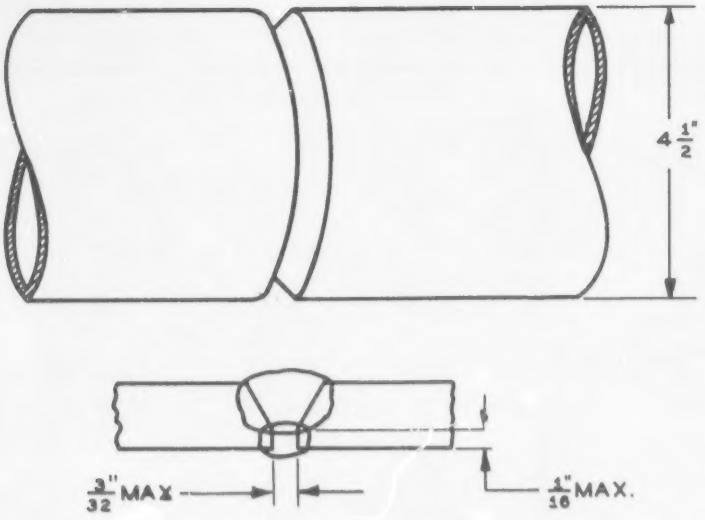

Figure 19. Butt Weld in Pipe.

1. Cut two pieces of pipe to the required length.

2. Clean and bevel the joint ends as shown in figure 19.

3. Set up work in V blocks or at an angle and tack weld at four equally spaced points.

4. Using one hand to turn the work, weld the first pass using a 1/8" diameter electrode.

5. Chip off the slag and inspect the weld for penetration and fusion.

6. Weld the second pass in the same manner using a 5/32" electrode.

QUESTIONS

Note: Answer all questions on a separate sheet of paper. DO NOT WRITE IN THIS STUDY GUIDE.

1. What is the purpose of the backing ring in butt welding pipe?

2. What is the purpose of a template?

3. How does the metal thickness affect the number of passes in butt welding pipe?

4. What are the advantages in wrinkle bending pipe?

5. How much pipe would be required to produce a 90° bend with an outside radius of 28 inches?

6. How is the spacing of the wrinkles determined?

7. Why is excess penetration undesirable in a butt weld?

8. What methods are used to bevel large diameter pipe of heavy wall thickness?

9. Approximately what size are the tack welds in comparison to metal thickness?

10. How can the alignment of pipe ends be maintained prior to welding?

REFERENCES

TO 34W4-1-5, Welding Theory and Application, Modern Welding Handbook.

Metal & NDI Branch
Chanute AFB, Illinois

HEAT AND CORROSION RESISTANT FERROUS ALLOYS

OBJECTIVES

After completing this study guide and classroom instruction, you will apply the techniques and procedures required to perform metallic arc welding of heat and corrosion resistant ferrous alloys.

INTRODUCTION

Heat and corrosion resistant ferrous alloys, sometimes referred to as stainless steel, have come into their present wide use mainly because of one characteristic they have in common. They are all resistant to heat and corrosion. This corrosion resistant quality is due to a chromium content in amounts over 10 percent. Other elements added to attain certain desirable properties are nickel, manganese, columbium, titanium, molybdenum, silicon, and carbon.

INFORMATION

MANAGEMENT OF DEFENSE ENERGY RESOURCES

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METALLIC ARC WELDING OF HEAT AND CORROSION RESISTANT FERROUS ALLOYS

As far as welding is concerned, practically all stainless steels can be divided into two general classes; those containing only chromium as the alloying element, and the austenitic types. The latter contains both chromium and nickel in varying amounts.

The first class, known as straight chromium stainless steels, are more difficult to weld than those containing both chromium and nickel. When metals in the first class are heated to melting temperatures, they are subject to rapid grain growth and do not respond to grain refinement through heat treating. Such alloys, when welded, possess very little ductility; therefore, welding is not recommended when the part is subjected to movement or shock at room temperatures.

The second class, or chromium-nickel group, is most highly recommended for welding. These metals, being of an austenitic nature, are extremely tough and ductile in the as-welded condition.

The techniques and procedures employed in welding stainless steel are different than those used in welding carbon steels. Not only must the strength of the base metal be maintained across the weld area, but, in practically all cases, the corrosion resistance must be retained as well. Frequently, welding must be done on thin gauges. Often, the appearance of a polished stainless steel surface must be protected. Preservation of these qualities rest not only in your ability as a welder, but also in your knowledge of stainless steels. You should know how each stainless steel is affected under the influence of heat and anticipate this effect so that you may control the damaging effects of welding.

The American Iron and Steel Institute has standardized stainless steel types by the use of a numbering system. Foldout 1 (located at back of this SG), shows the common types of stainless steels, their approximate chromium-nickel content, usage, and general characteristics.

Fusion welding by use of the metallic arc is used in the fabrication of stainless stainless steels. For best results in welding, stainless steel should not be held at the melting temperature too long. This causes loss of corrosion resistance, warpage, and undesirable grain growth. Metallic arc welding can help you to avoid these harmful effects because the heat application is immediate in this

method. In making a weld, the metal deposited and the joint edges are heated to the melting temperature of about 2690°F. The body of the work, however, remains cold. This causes a zone parallel to and near the weld which is heated between 1000° and 1500°F, causing carbide precipitation. Since arc welding is rapid, this zone is quite narrow and close to the weld. The deposit cools quickly resulting in a minimum of heat build-up adjacent to the weld. This allows the laying of a deposit which can be accurately controlled. Good control is also possible because the composition of the weld metal deposit is the result of two known compositions, that of the metal being joined and the metal in the electrode. Where metal thickness permits, metallic arc welding of stainless steel jet engine and reciprocating engine exhaust manifolds is highly recommended for the following reasons:

1. The intense heat of the arc permits faster welding speeds with minimum heat input and warpage of the part.

2. The coating of the electrode provides a fluxing action, protective gas shield, and slag covering during deposit of the electrode and cooling of the weld metal.

3. Various electrode combinations are available which make it possible to compensate for loss of certain elements such as chromium and columbium during welding.

Since many jet engine parts are fabricated of very thin stainless steel, arc welding is restricted to parts in which heavier gauges of metal are used. Other aircraft parts, such as exhaust manifolds and collector rings, are fabricated and sometimes repaired by this method.

SELECTION OF ELECTRODE, POLARITY, AND CURRENT SETTING

Electrode

The composition of electrodes for the welding of stainless steel is of critical importance from the standpoint of corrosion resistance and tensile strength. This is especially true of numerous jet engine repairs where the weld deposit must meet exacting requirements. Manufacturers of electrodes must meet certain commercial and military standards, which are established by the steel industry and using agencies.

Specifications of welding electrodes for heat and corrosion resistance steels are contained in military specification MIL-E6844A. Electrode composition, commercial designation, and color identification for each is shown in Foldout 1. The method of marking electrodes by color is shown in figure 20. In requisitioning electrodes from federal supply catalogs, the military specification number will be shown as part of the item nomenclature. Positive electrode identification can be made by reference to MIL-E6844A.

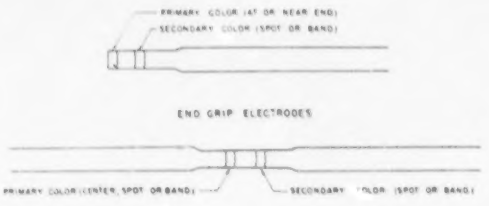
PRIMARY COLOR (AT OR NEAR END)
SECONDARY COLOR (SPOT OR BAND)
END GRIP ELECTRODES
PRIMARY COLOR (CENTER, SPOT OR BAND)
SECONDARY COLOR (SPOT OR BAND)

Figure 20. Color Marking for Electrode Identification.

Electrode manufacturers consider certain elements lost as they pass through the arc. Such losses are compensated for by an increase in known volatile elements in order to produce welds whose composition will be close to that of the base metal. Approximately 30 percent of the columbium in an electrode will be lost in welding. In welding 18-8 stainless steel, an electrode containing 19 percent chromium and 9 percent nickel is often used. Titanium cannot be transferred from the electrode through the arc and for this reason titanium bearing rods are not used in arc welding.

Polarity

Direct current with reverse polarity is generally used for metallic arc welding of stainless steel. This places the hotter hotter end of the welding circuit at the tip of the electrode. This causes faster

melting; therefore, faster depositing of filler metal from the electrode. It also results in less heat input to the base metal being joined. Straight polarity is sometimes used on heavy gauges of stainless steel.

Current Setting

The welding current should be adjusted to provide only enough current to ensure good fusion. Lower current settings are required more for stainless steels than for ordinary steels of equal thickness because they possess a lower heat conductivity than common steels. This tends to keep the heat of the arc localized at the point of contact rather than allowing it to travel back into the plate. Stainless steel will also penetrate much better than steel because it is very fluid when molten; whereas ordinary steel tends to be more viscous and sluggish. Foldout 1 lists average current settings for the most frequently used sizes of electrode. Other factors, such as metal thickness, mass of metal, type of stainless steel and the ability of the operator must be considered in determining exact current settings for a particular welding job.

Procedures for Butt Joints in the Flat Position

The following are general procedures to be used when welding butt joints in the flat position.

1. Clean the surfaces of the metal arc to be welded (1/8" x 6" x 6").

2. Set up the joint with proper spacing and tack weld the ends.

3. Hold the proper arc length to ensure good fusion.

4. Weld the butt joint according to weld specifications.

5. Check the weld for contour of bead, penetration at root, and slag inclusions.

Procedures for Tee Joints in the Horizontal Position

The following are general procedures to be used when welding tee joints in the horizontal position.

1. Clean surfaces of the metal area to be welded (1/8" x 1-1/2" x 6").

2. Set up the joint with proper alignment and tack weld the ends.

3. Hold the proper arc length to ensure good fusion.

4. Weld the tee joint according to weld specifications.

5. Check the weld for contour of bead, penetration at root, and slag inclusions.

Procedures for Lap Joints in the Flat Position

The following are general procedures to be used when welding lap joints in the flat position.

1. Clean surfaces of the metal area to be welded (1/8" x 2" x 6").

2. Set up the joint with proper overlap (approximately 3/4") and tack weld the ends.

3. Hold the proper arc length to ensure good fusion.

4. Weld the lap joint according to weld specifications.

5. Check the weld for contour of bead, penetration at bottom of plate, and slag inclusions.

QUESTIONS

Note: Answer all questions on a separate sheet of paper. DO NOT WRITE IN THIS STUDY GUIDE.

1. Why are stainless steels commonly known as heat and corrosion resistant steels?

2. Into what two general classes can stainless steels be divided?

3. List by type number the stainless steels used to fabricate gas turbines, exhaust systems, and exhaust manifolds.

4. What factors must be considered in order to produce good welding results in stainless steel?

5. Why is the composition of the electrodes for welding stainless steels critical?

6. How are the various types of welding electrodes identified?

7. What polarity is used to metallic arc weld stainless steel?

8. How do current settings differ between ordinary steels and stainless steels?

REFERENCES

TO 34W4-1-5, Welding Theory and Application, Modern Welding Handbook (Chapter 18).

Metal & NDI Branch
Chanute AFB, Illinois

CAST IRON

OBJECTIVES

After completing this study guide and classroom instruction, you will apply the techniques and procedures required to perform metallic arc welding of cast iron.

INTRODUCTION

Cast iron is a combination of iron and carbon with other elements picked up during the refining process. The carbon content of cast iron may vary from 1.7 to 4.5 percent. It is the high carbon content that gives the cast iron its dark color.

There are three types of cast iron used in industry: gray, white, and malleable. Gray cast iron is made by slowly cooling the molten iron, white cast iron by quickly cooling the molten iron, and malleable cast iron by heat treating white cast iron.

INFORMATION

MANAGEMENT OF DEFENSE ENERGY RESOURCES

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WELDING CAST IRON

Cast iron is an alloy of iron containing a high percentage of carbon and is made in cast form. The carbon content is usually from 1.7% to 4.5%. Cast iron generally contains small percentages of silicon which act as a fluxing agent and improves fluidity. Alloys of cast iron contain such elements as nickel, chromium, molybdenum, vanadium, titanium, aluminum, and copper. General characteristics of cast iron include hardness, brittleness, great compressive strength, low tensile strength, high shock resistance, wear resistance, and corrosion resistance. It is not malleable at any temperature and has a tendency to crack if it is subjected to quick changes in temperature. For this reason, it cannot be forged, rolled, twisted, or bent. Its low melting point, fluidity, and fusibility make it an excellent metal for casting.

Gray cast iron is the most common type. When this cast iron is fractured, the break appears gray because the surface is covered with free graphite.

White cast iron contains carbon in the combined form. It is readily distinguished by its hardness and brittleness and when fractured, the break appears silvery and white with little or no visible graphitic carbon. White cast iron is produced by rapid quenching from the molten state. It is available in various compositions, some of which are used in making malleable iron castings.

Malleable cast iron is produced by prolonged annealing of white cast iron. This annealing causes a decarburized steely skin and a dark core of tempered carbon. These castings will bend before breaking and are more suitable to use when shock occurs.

Metallic Arc Welding

Metallic arc welding is the only welding process adaptable for certain cast iron applications. Examples of this are found frequently in castings which permit the use of only a limited amount of heat and in jobs which require welding to be done in the overhead position. This latter is usually prohibitive by other methods because of the fluidity of the molten metal. Cast iron can be welded with heavy-coated monel or 18-8 type stainless steel electrodes. Other high-nickel rods such as "nirod" and "nicast" can, with proper precautions, produce a fairly machinable weld. Various types of mild steel electrodes

such as "strongcast" and "ferroweld" are available for arc welding of cast iron when a nonmachinable weld is satisfactory. Bronze electrodes are also available for joining cast iron, cast iron to steel, or any other combination of bronze and iron based alloys. These electrodes are recommended for malleable iron castings.

Metal Preparation

The edges of the joint should be chipped out or beveled by grinding to form a 60-degree included angle bevel. The vee should extend to within 3/32" from the bottom of the crack. Always maintain original alignment of the parts. Where a crack is to be welded, a small hole should be drilled in the casting at each end of the crack to prevent it from lengthening when the welding heat is applied.

Studding

Where maximum strength is necessary in heavy cast iron parts, studs of steel approximately 1/4" to 3/8" diameter should be used (refer to figure 21A). The cast iron should be veed out, drilled, and tapped along the vee so that the studs may be screwed into the casting. A coarse threaded bottoming tap should be used. The studs should project 3/16" to 1/4" above the cast iron surface. The studs should be long enough to be screwed into the face of the casting and to a depth of at least the diameter of the studs. The cross sectional area of the studs should be 25% to 35% of the area of the weld surface. It is good practice to first weld one or two beads around each stud, making sure fusion is obtained with the stud and cast iron base metal. Straight lines of weld metal should be avoided as much as possible. Welds should be deposited intermittently and each bead peened before cooling. Where it is difficult to apply studs to a joint, the edges of the casting can be machined or chipped out with a round nose tool to form a long U-shaped groove on the surface and face of each bevel, as shown in figure 21B. These grooves serve as anchors for weld metal deposited in the joint and helps to increase its strength mechanically.

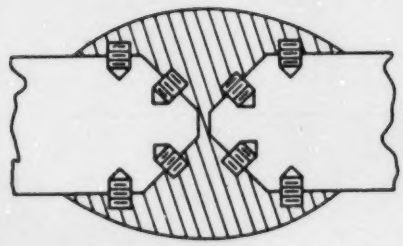

Figure 21A. Method of Reinforcing Cast Iron Welds.

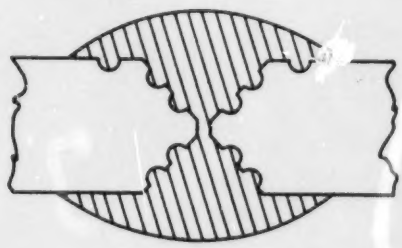

Figure 21B. Method of Reinforcing Cast Iron Welds.

Welding Procedure

Reverse polarity with a minimum current setting should be used for metallic arc welding of cast iron. Foldout 1 lists recommended current settings for cast iron type of electrodes.

Welding should proceed with stringer beads approximately 1" in length. Each bead should be allowed to cool before proceeding with the next bead. In some cases the skip procedure should be used. Each short length of weld should be peened lightly immediately after the bead has been deposited. It should also be allowed to cool before additional weld metal is deposited. The peening action gives a forging effect to the metal and helps relieve the stresses set up by uneven cooling. Peening reduces the danger of cracking in the weld or base

metal. The cooling between beads reduces the amount of heat inducted into the part. Using a small diameter electrode also helps to reduce the amount of heat inducted. Weaving of the electrode should be kept to a minimum. Each bead must be cleaned thoroughly by chipping and wire brushing before additional metal is deposited.

QUESTIONS

Note: Answer all questions on a separate sheet of paper. DO NOT WRITE IN THIS STUDY GUIDE.

1. What is recommended included angle of a cast iron butt joint?

2. Which type of cast iron is annealed?

3. Why is peening used on cast iron?

4. What is the principal drawback in welding cast iron?

5. What is studding?

REFERENCES

TO 34W4-1-5, Welding Theory and Application, Modern Welding Handbook.

Metal & NDI Branch
Chanute AFB, Illinois

HARD SURFACING, CUTTING, AND RESISTANCE WELDING

OBJECTIVES

After completing this study guide and classroom instruction, you will apply the procedures and techniques in metallic arc hard surfacing and cutting, and resistance welding.

INTRODUCTION

The hard surfacing process has been used for a long time to increase the service life of equipment used in construction and mining operations. The proper application of hard surfacing material can increase the service life of any given piece of equipment from two to 25 times. Imagine the cost involved in a road building operation or a mining operation if hard surfacing were not done.

It is important to know how to save Air Force equipment and material; however, it is just as important to know how to dispose of it once it is no longer of any use. Many items must be reduced to a manageable size and separated by types of material. In many cases this is done by means of metallic arc cutting.

You are now familiar with the methods used to join metal. You know when and how each method is applied. What happens then when a metal is too thin for normal welding methods? You must learn a new method known as resistance welding. This method was designed for metals that are too thin to be joined by other methods.

A resistance welder known as a foil welder has been developed for use on metals too thin for other resistance welders. Its primary purpose is for repairing insulating blankets used on jet engines.

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HARD SURFACING AND RESISTANCE WELDING PRINCIPLES

The principles involved in metallic arc hard surfacing are basically the same as those of oxyacetylene hard surfacing. The major difference is in the method of application. The advantages of the arc process become readily apparent when you have to build up and hard surface a large item or area. In most cases, there is little or no preheating since the arc supplies the heat.

Spot, flash, and seam are resistance welding processes. The required heat at the joints to be welded is generated by the resistance offered by the work parts to the relatively short time flow of low-voltage, high-density electric current. Heat developed in this manner is sufficient to raise the temperature of the metal in a very localized area to a plastic state. The maximum temperature achieved is ordinarily above the melting point of the base metal. Pressure is then applied through the electrodes, which forge the parts together. The weld is made between the sheets to form a spot or weld nugget. Spot welds properly spaced and of specified size produce joints comparable in strength to joints that are fusion welded.

The various types of resistance welding processes differ in equipment design and welding technique. All processes, however, have one common feature - no filler rod is added to the weld. Recent improvements in the design of resistance welding machines and the development of special alloys for aircraft and missiles have brought about an

increased use for this process in the fabrication of parts. Spot and seam resistance welding has almost totally replaced the use of riveted joints. This new method produces assemblies with a smooth outer surface which are light in weight and high in strength. Also, the effects of expansion and contraction common to the fusion welding processes of oxyacetylene and metallic arc are overcome by resistance welding.

The metal foil welding machine is designed primarily for assembly and repair of stainless steel foils which are used as insulation blankets on some types of jet engines. Insulation blankets are used to hold in the heat of high temperature exhaust sections which helps to maintain maximum engine performance. These blankets also act as protective shields to prevent high exhaust temperatures from coming into contact with structural members of the aircraft which could weaken or destroy them. Insulation blankets are frequently damaged during the removal of the engine from the aircraft. The type of damage may be snags, tears, pinholes, or punctures which must be repaired before being reinstalled.

Recently, the metal foil welding machine has been used in the assembly of stainless steel honeycomb structures which are being used as structural support members in our latest supersonic aircraft.

HARD SURFACING ALLOYS

There are many types of hard surfacing alloys. Each alloy is specifically designed to provide properties which are best adapted to combat the destructive forces met in a given operation. In any type of mechanical operation, moving parts are subject to wear which results in a loss of material. Hard surfacing reduces wear. Hard surfacing alloys are used, not only to protect new parts to ensure greater efficiency, but to repair worn equipment. No single hard surfacing material is satisfactory for all applications. Many types of hard facing alloys have been developed to meet the various requirements for hardness, toughness, shock, wear resistance, and other special qualities. These alloys are generally classified into five broad groups.

Group 1 Alloys

The alloys in this group consist mainly of an iron base and less than 20 percent alloying elements. These are mainly chromium, tungsten, manganese, silicon, and carbon. Group 1 alloys have greater wear resistance than any machine steel. Although not as hard, they have greater toughness and shock resistance than other hard facing alloys. They are used to build up badly worn sections before applying a final harder surfacing alloy of better grade. These alloys are used for rock crushing and similar equipment where resistance to shock and impact are most important and hardness is only secondary.

Group 2 Alloys

The alloys in this group consist of an iron base of 50% to 80% iron with the remainder being the same elements which are used in Group 1. Small percentages of cobalt and nickel are sometimes added. Some of these alloys have the property of "red hardness" which is the ability to remain hard at a red heat. These alloys are used for final hard wear resisting surfaces after the part has been built up with a high strength rod.

Group 3 Alloys

The alloys in this group consist of the nonferrous alloys of cobalt, chromium, and tungsten, as well as other nonferrous hard surfacing materials. Some of these alloys also have the property of red hardness. These alloys are available in different grades, all of which are highly resistant to wear and possess a toughness and strength which give them a wide range of application. Valves made from these alloys are designed for handling gas, oil, acids, and high temperature and high pressure steam. These alloys are used extensively for the valve seats in internal combustion engines.

Group 4 Alloys

The alloys in this group consist of the carbide materials or diamond substitutes and are the hardest and most

wear resistant of all the hard surfacing materials. Some of these alloys contain 90% to 95% tungsten carbide, with the remainder being cobalt, nickel, iron, or similar metals. These give strength, toughness, heat resistance, and impact strength to the tungsten carbide. Some of these alloys are almost pure tungsten carbide and contain no alloying elements. Alloys of this group are furnished in the form of small castings. They are welded to the surface of the metal or other hard surfacing material. This application of tungsten carbide pieces to wearing surfaces is known as "hard setting."

Group 5 Alloys

The alloys in this group consist of crushed tungsten carbides of various sizes. These may be fused to strips of mild or low alloy steel, embedded in hard surfacing material, high strength rod, or packed in mild steel tubes of various diameters. All of these are available in short lengths which may be applied to the wearing surface as welding rod. Crushed tungsten carbides are also available in loose form as granular pieces or powder which may be sprinkled onto the wearing surface and melted into it. The alloys in this group, although more expensive than other types, are used for many applications because of their long life.

HARD SURFACING

Most metals and their alloys can be readily hard surfaced with the exception of copper, aluminum, and their alloys. These metals cannot be satisfactorily hard surfaced because of their low melting points. In some cases, heavy sections of brass, bronze, and copper can be hard surfaced by preheating to a red heat and then applying the Group 3 alloys. Hard surfacing alloys can be applied to the following metals and alloys:

1. Low and medium carbon steels with a carbon content of 0.50% or less.

2. High carbon steels, if they are heat treated before and after hard surfacing to remove hardness and brittleness to prevent cracking.

3. Low alloy steels, depending upon the base metal. Heat treatment is required after hard surfacing.

4. Manganese steels, which are hard surfaced by the metallic arc welding process. Care should be taken to avoid overheating this metal and to apply the welding heat in order to heat the part uniformly. The deposit should be peened to relieve cooling stresses.

5. Stainless steels, including the high chromium and chromium-nickel steels. The physical properties of the particular steel should be known in order to maintain the corrosion resistance after hard surfacing. Uniform heating and cooling help to prevent warping and cracking due to the higher coefficient of expansion of the stainless steel.

6. Gray cast iron. Since the melting point of cast iron is lower than steel, special precautions should be taken in working with thin sections.

7. Malleable iron. The malleable iron surface beneath the hard surfacing layer hardens. Some of this hardness can be removed by reheating the metal to approximately 1500°F.

Metal Preparation

The surface of the metal to be hard surfaced must be cleaned of all scale, rust, dirt, or other foreign substances by grinding, machining, or chipping. When these methods are not available, the surface may be prepared by filing, wirebrushing, or sandblasting. The latter methods are not as satisfactory since small particles of foreign matter which remain on the surface must be floated out during the hard surfacing operation. All edges of grooves, corners, or recesses must be well rounded to prevent overheating the base metal.

Preheating

The same precautions for preheating should be taken in hard surfacing as are for welding the particular base metal. If possible, steels in the heat treated condition should be annealed before the hard surfacing layer is applied.

Quenching in water will crack the hard surfacing layer. When it is necessary to heat the metal to the critical temperature after hard surfacing, oil should be used as the quenching medium. When it is impossible or undesirable to anneal high carbon steel or high tensile low-alloy steel, the hard surfacing alloy is deposited by the transition bead method. This is done by first depositing a thin layer of stainless steel, such as the 25 percent chromium/20 percent nickel rod or the 18 percent chromium/8 percent nickel rod. Next, build up the section to approximately the original dimension, using an 11 to 14 percent manganese or high strength rod, and then finish by hard surfacing with one of the Group 2 alloys.

Deposit Thickness

Depending upon the specific application, worn sections are rebuilt with hard facing deposits ranging from 1/16" to 1/4" in thickness. When it is necessary to deposit hard surfacing material in excess of 1/4", the part is rebuilt with the Group 1 alloys to within 1/16" to 1/4" of the finished size. The final deposit, consisting of Group 2 or 3 alloys, is added with some excess to permit grinding to the desired finished dimensions. When harder and more brittle Group 4 and 5 hard surfacing materials are applied, either as a final deposit or in a single layer, the shape of the deposit should be carefully controlled. This is important in order that impact or shock loads may be transmitted through hard surfacing metal into the tougher base metal. When not backed up by tough base metal, corners, sharp edges, or built-up sections will chip or break off in service.

Application

Every hard-facing metal, except some of the Group 4 and 5 alloys, is applied with either coated or base electrodes, using reverse polarity. The flux coating on coated electrodes reduces spatter loss, assures good penetration, prevents oxidation of the deposited metal and helps to stabilize the arc. The bare hard-facing electrodes are used when it is necessary to apply a heavy bead or to deposit the metal against a copper form. For best results, the filler metal should be deposited by using a long arc. Foldout 1 may be used as a guide in selecting the current settings for hard-facing electrodes.

Procedures

The following are general procedures to be used when hard surfacing metals (Low carbon plate).

1. Select a low carbon plate measuring 3/8" x 6" x 6" and secure Toolweld Number 55 electrode 1/8" diameter (Group 1).

2. Clean the surface to be hard-faced.

3. Bevel the edge of the metal plate to 60°.

4. Apply hard-facing material to the beveled part of the plate.

5. Inspect the weld for porosity, overlapping, burnt, and insufficiently built-up edges.

6. Grind the surface smooth and check for proper cutting edge.

ARC CUTTING

Most metal can be cut by the metallic arc process. The metallic arc process depends on gravity, heat, and force of the arc to remove the molten metal from the kerf. Oxidation (burning of the metal) does not take place as in oxyacetylene cutting.

Arc cutting is used for cutting of scrap steel, for preparing metal prior to welding, cutting heavy castings, and cutting nonferrous metals. The last application makes the process adaptable to the scrapping of salvaged aircraft. Cuts made with the metallic and carbon arc electrodes are rough and irregular and are not as clean as cuts made by the oxyacetylene process.

Metallic arc cutting is best performed by using mild steel electrodes of down-hand (flat) deep groove type with a heavy coating. The heavy coating burns more slowly and serves as an insulator,

Electrode Diameter	Current
1/8	200 amp
5/32	300 amp
3/16	400 amp

Table 1. Current Requirements for Metallic Arc Cutting.

preventing arcing to the sides of the kerf. Current requirements for metallic arc cutting are given in table 1.

It will be noted that the current requirements for metal arc cutting are much higher than those used for metallic arc welding. Polarity adjustments are consistent with recommendations of the manufacturer. When lacking this information, experiment until desired results are obtained. In starting the cut, the arc is held at the point selected until the metal begins to flow. The arc is then moved along at a rate which permits the molten metal to continuously flow out of the cut, as shown in figure 22.

Figure 22. Metallic Arc Cutting Removing Cast Iron Gear.

RESISTANCE WELDING

Spot Welding

This is the most widely used resistance welding process. The name "spot welding" is derived from the fact that the weld is made at one point or spot between the electrode, as shown in figure 23.

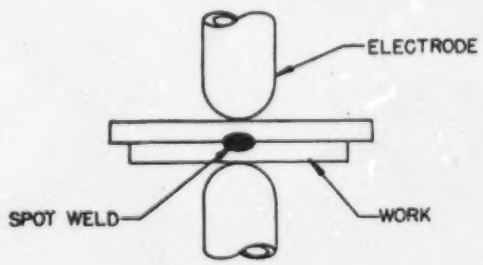


Figure 23. Spot Welding.

Spot welding machines are manufactured in a variety of types and sizes but are usually classed as "ROCKER ARM" or "PRESS," depending upon the movement of the upper arm. The rocker arm machine, shown in figure 24, is so named because the upper arm is pivoted and swings in an arc. These machines are used for welding light gauge metals. The press type spot welder has a straight up and down movement of the upper arm similar to that of a punch press.

In addition to these, there are multiple spot welders that make several spot welds with one movement of the upper arm. Portable gun spot welders are used

on parts and assemblies that would not fit into the throat of conventional machines. The control panel and transformer of portable machines may be suspended from overhead rails and moved freely about the work area.

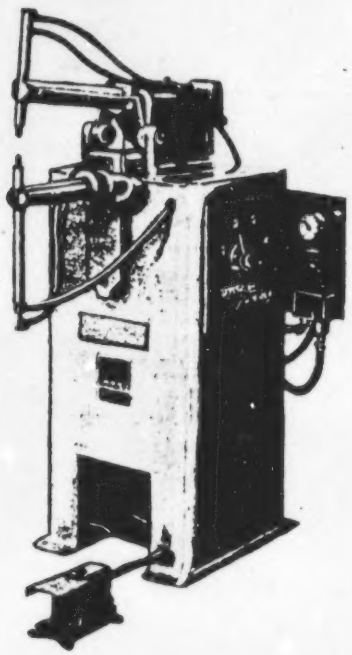


Figure 24. Rocker Arm Type Spot Welder.

"Seam" or "Roll" Welding

This is a resistance welding process similar to spot welding except that the electrodes used in the latter method are replaced by copper alloy wheels or rollers. The work is placed between the rollers and pressure is applied to hold the parts in close contact. One of the wheels is motor-driven at an adjustable speed. The speed at which the work is moved and length of time that current flows may be regulated to produce overlapping welds and gas-tight seams, as shown in figure 25, or they may be spaced an inch or more apart. This machine is widely used in manufacturing jet engine inner and outer combustion chambers and tail cone assemblies, aircraft and automobile fuel tanks, and other liquid or gas-tight assemblies.

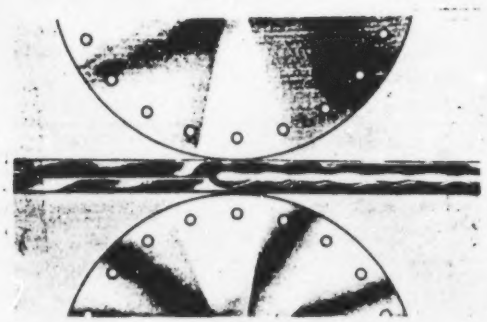


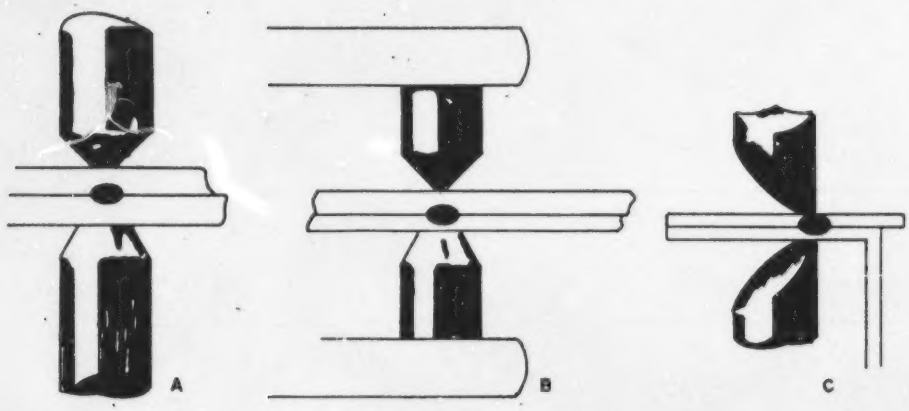
Figure 25. Cross Sectional View of a Seam Weld.

Spot Welding Electrodes

Electrodes are made of copper alloy with a hardness of at least 70 on the Rockwell B scale and at least 80% electrical conductivity. Although these electrodes are simple in design, local manufacturing from warehouse stocks of ordinary copper is not recommended. They may deform under high pressure and may be low in electrical conductivity. The radius of the electrode contact face determines the size of the spot weld. If the contact face is too small, the weld may be sound but low in total strength. If the contact face is too large, a higher current will be required to overcome the increased resistance. This condition can cause localized heating and result in poor weld surface appearance.

Electrodes are made in many different shapes and sizes, depending on the design of the part to be welded and desired size of the spot weld (figure 26). Regardless of the shape of electrodes, provisions must be made for keeping them cool. This is accomplished by machining a recess to within 3/8" of the contact face. Water is circulated through this recess at the rate of one gallon per minute to cool them and to prevent surface fusion of electrodes and work.

A rule to follow when selecting electrodes for a given job is to select one with a contact face diameter equal to four thicknesses of one of the sheets to be welded. Pressure on the electrodes may be varied slightly to produce



A. FOR WELDING METALS OF DIFFERENT CONDUCTIVITY.
B. FOR WELDING METALS OF DIFFERENT THICKNESSES.
C. FOR WELDING CLOSE TO AN ANGLE.

Figure 26. Various Types of Electrodes.

indentation and thereby arrive at the proper diameter contact area and spot weld.

After being in service, electrodes will develop flat surfaces and flash pits. They should be inspected regularly and redressed with an electrode-die-point dresser and rough (75-100 grit) emery cloth or paper.

Maintenance of Resistance Welders

Like any machine, continued operation of a resistance welder depends upon proper care and maintenance. The following preventive maintenance operations should be performed on all resistance welders.

1. Clean contact surfaces of the lower hornways with steel wire every six months when welding steel and every month when welding aluminum.

2. Clean contact surfaces of electrodes and electrode holders with steel wool every week, as shown in figure 27.

3. Clean contact surfaces between lower horn and horn bracket with steel wool every week.

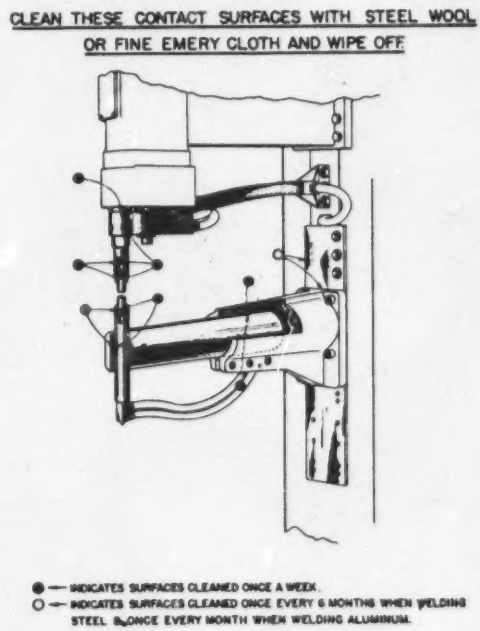

CLEAN THESE CONTACT SURFACES WITH STEEL WOOL
OR FINE EMERY CLOTH AND WIPE OFF
● — INDICATES SURFACES CLEANED ONCE A WEEK.
○ — INDICATES SURFACES CLEANED ONCE EVERY 6 MONTHS WHEN WELDING STEEL & ONCE EVERY MONTH WHEN WELDING ALUMINUM.

Figure 27. Surfaces to be Cleaned.

4. Lubricate ways of upper press arm (or swivel) each eight hours of operation.

CLEANING AND WELDING

Carbon Steel

CLEANING. Greasy or oily steel should be degreased in a vapor degreaser or as specified in technical order "Cleaning of Aeronautical Equipment." Mill scale, present on hot rolled steel, may be removed by steel grit blasting, wire wheel buffing, or by the manual application of emery cloth. Sandblasting should be avoided as particles of silicious material may remain on the metal surface and cause highly erratic surface resistance conditions, spitting, and expulsion of the molten metal. The operator should avoid touching the cleaned metal surface with the hands since the film of deposited oil and moisture affect the quality of the weld.

WELDING. Carbon steel is the easiest of all metals to weld. It has a wide plastic range and can be welded with a variety of current, pressure, and time settings. It should be remembered, however, that all resistance welding operations should be preceded by a series of experiments to determine what control settings are best for a given job. Variation in line voltage, water pressure, air pressure, and cleanliness of parts to be welded prevents prescribing specific control settings.

Stainless Steel

CLEANING. Cleaning of stainless steel is usually limited to removing dirt, oil, or grease in a vapor degreaser or manually with a degreasing agent. After being in service at elevated temperatures, stainless steel develops a ceramic coating that acts as an insulator between the electrodes and work. This coating resists the action of a wire wheel but is easily removed by soaking the part for a few minutes in molten caustic. The caustic bath should be followed immediately by a cold water rinse to remove, or neutralize, all traces of the caustic solution.

WELDING. Stainless steel is easily welded but requires exacting control of time and pressure. The electrical resistance of stainless steel is greater than that of carbon steel and the thermal conductivity less; therefore, it requires less welding current and a corresponding increase of pressure. Stainless steel should be welded as rapidly as possible because of the danger of carbide precipitation between 800 and 1500°F.

Inspection and Testing of Spot Welds

INSPECTION. The outer surface of a good spot weld should be smooth, free of cracks, essentially free of tip pickup and flash pits. Internal inspection of a weld may be made by lap welding two coupons (1 x 5 inches), as shown in figure 28, and shearing in a vise. The sheared weld should present a round, fine grained, rough fused area. The rough weld area is proof that a good bond was obtained and that chunks of metal from one coupon have fused into and pulled away from the other coupon. The sheared section should then be inspected under a microscope to determine grain size and to check for minute cracks. If the sheared weld appears to be satisfactory, another weld should be made, sectioned 1/32" above weld center, polished, etched, and again examined under the microscope. The etched weld should be an oval approximating an ellipse. Penetration should be at least 20% of the sheet thickness (one sheet) and should not exceed 80% of sheet thickness.

Figure 28. Lap Welded Coupons.

TESTING. After a weld has passed visual inspection, described in the preceding section, two coupons should be lapped and welded for a tensile test, as shown in figure 29. The weld is

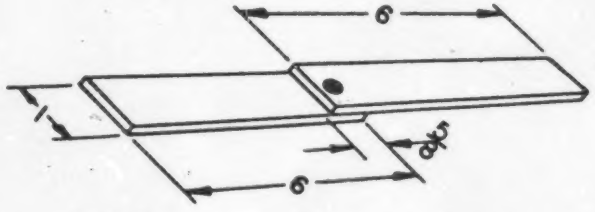


Figure 29. Tensile Test Coupon.

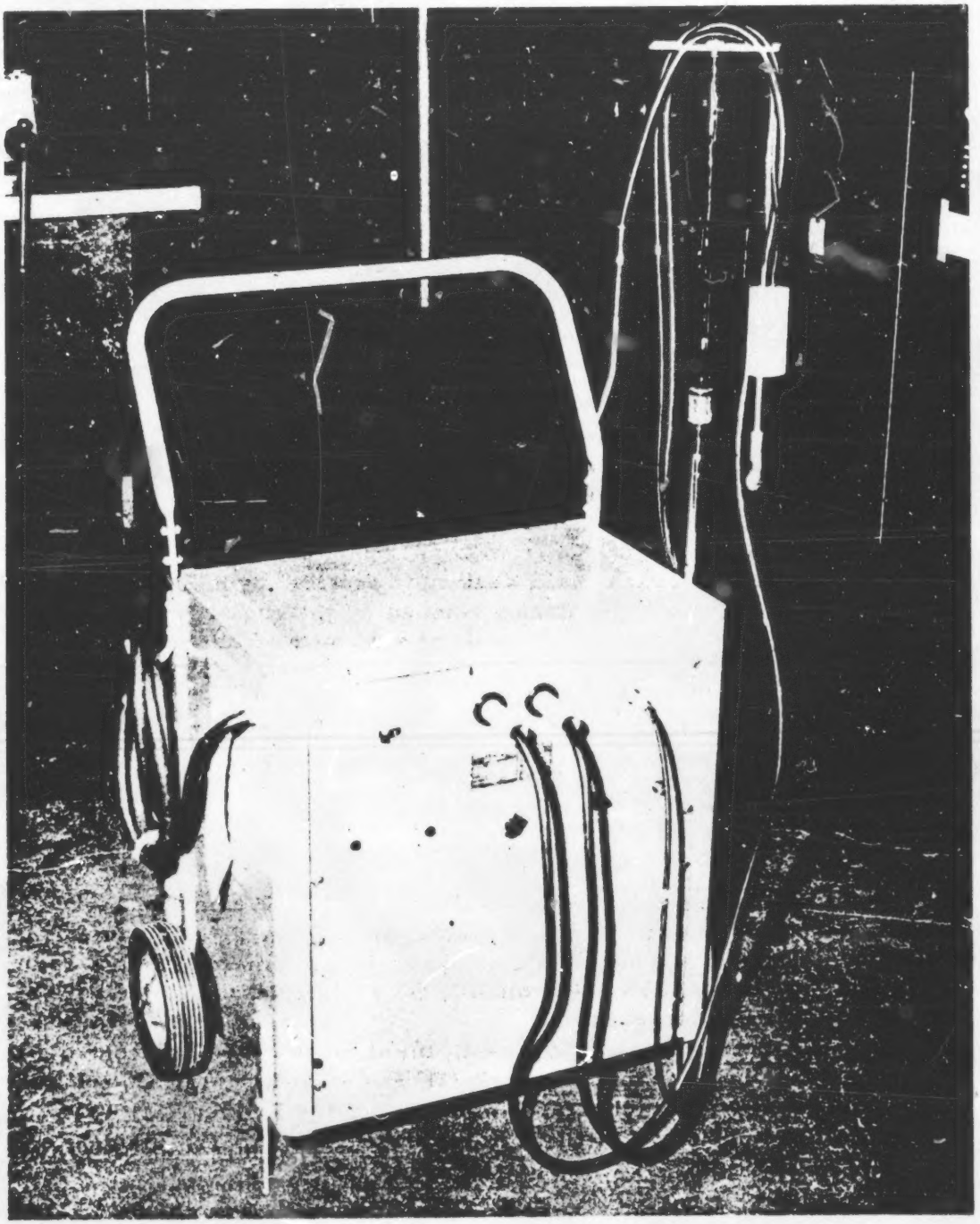


Figure 30. Vacuum Tube Welder.

considered satisfactory if it pulls above the minimum weld strength specified in the table for that type metal.

FOIL WELDING

Metal Foil Welding Unit

COMPONENTS. The VTW-1M (Vacuum Tube Welder) in figure 30 is an enclosed unit which consists of a welding transformer, auto-transformer, fractional cycle timer, and an adjustable speed repeat timer. The power input required is single phase, 205-240 volt AC, 50-60 Hertz.

CONTROL PANEL. In figure 31, the controls, their arrangement, and their location on the panel can be seen. (1) Power switch, (2) output receptacles, (3) actuator receptacle, (4) welding indicator lights, (5) weld power control switch, (6) repetition rate control switch, (7) single-repeat switch.

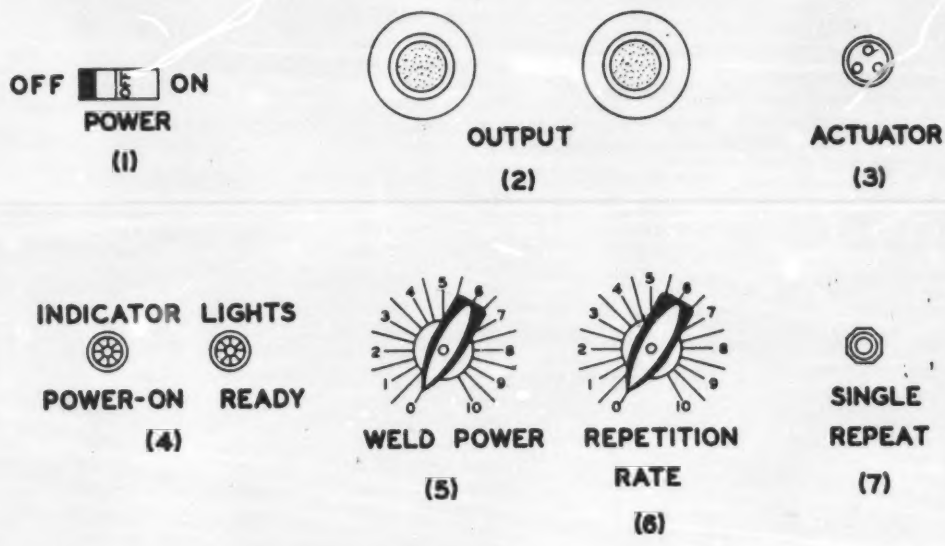


Figure 31. Control Panel.

Types of Insulation Blankets

Foil and mesh insulation blankets are used on various parts of the exhaust section of jet aircraft. In figure 32, the foil blanket is constructed with insulation material placed between two thin sheets of foil. The mesh type insulation blanket is constructed in the same manner except that a wire mesh is added to the outside of the blanket for greater reinforcement and protection from damage.

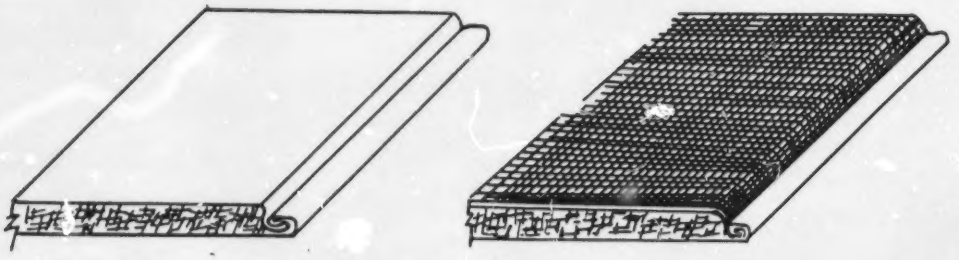
FOIL TYPE. The metal foil is a corrosion resistant steel, type 321 or 347, and the thickness may vary from .002 to .008 depending on where the insulation blanket is to be used.

1. All cracks, tears, pinholes, and/or punctures in the skin or foil of the blanket, over an area of 15 degrees on each side of the blanket installation bottom center line, must be repaired.

2. Patches must overlap 1/4" and light, overlapping spot welds used to make a tight repair.

3. In the remaining blanket area, patches may be installed by spacing spot welds in a straight or staggered line pattern. Figure 33 lists type of damage and typical repairs.

MESH TYPE. The mesh type insulation blanket is fabricated differently from the foil type. A wire mesh is added on



Foil Type

Mesh Type

Figure 32. Types of Insulation Blankets.

Damage	Repair
Pinholes, tears or cuts in skin of blanket.	Seal with 0.002 inch to 0.004 inch corrosion resistant steel foil, type 321 or 347. Attach to blanket using light spot weld.
Tear or cutout in edge of blanket.	Patch with 0.002 inch to 0.004 inch corrosion resistant steel foil, type 321 or 347, wrapped around edge of blanket. Attach to blanket using light spot weld.
Wrinkled blanket edges.	Flatten out wrinkles. Check for tears and cuts. If any are present, repair as described in preceding step.
Torn out grommets.	Patch skin area with 0.002 inch to 0.004 inch corrosion resistant steel foil, type 321 or 347, allowing 0.25 inch patch overlap. Attach to blanket using light spot weld. For torn edge, wrap sheet around edge, overlapping torn edge sufficiently to obtain good weld seal joint. Punch or cut out hole for grommet, and install new grommet. If grommets are not available, seal edge of hole by overlapping spot welding around hole.

Figure 33. Types of Damage and Typical Repairs.

the exterior side to protect the foil from damage. It is placed on the blanket as a reinforcement to prevent tearing or snagging of the foil during maintenance and handling. The mesh blanket may be repaired by the following steps:

1. Inspect the blanket carefully for snags, tears, or punctures in the wire mesh.

2. A mesh type insulating pad with tears in the wire mesh may be repaired, provided the damage is not more than 36 square inches in any one area.

3. Mesh repair patches must overlap the damaged area approximately one inch and be secured in place with .032" steel bostitch staples or laced with safety wire. The staples should be located at one-half inch intervals.

Caution: Do not staple through the pad or foil.

4. Patch repair small areas which have become separated or matted.

Insulation Blanket Repair

In order to properly repair insulation blankets with the least amount of difficulty, the following should be observed:

1. The insulation blanket must be cleaned prior to welding. No attempt will be made to clean the blanket with a solvent soaked rag, or to remove discoloration which remains after vapor degreasing.

2. Accumulations of hard crusted material will be removed by cutting out the area or areas and patching done within prescribed limits.

3. Use duck bill snips or scissors to trim foil to required size for patching, allowing a minimum of 1/4" edge distance for lapping all around.

4. Patch material must be clean and the edges smooth. Form patch to fit the grooves of the blanket when necessary.

Procedures for Machine Setup

1. Connect metal foil welding machine to power source.

2. Connect ground cable and either the spot or seam welding handpiece to the front panel receptacles marked "OUTPUT."

3. Insert actuator plug into the receptacle marked "ACTUATOR."

4. Turn on POWER switch - a red light will indicate that power has been applied.

5. After a one minute time lapse a green light will indicate that the unit is ready for operation.

Note: Material to be repaired must be cleaned prior to welding. Keep welding electrodes clean. Electrode pressures must be held as uniform as possible.

Procedures for Spot Welding

1. Set SINGLE-REPEAT switch to "SINGLE."

2. Set WELD POWER CONTROL switch at low value if light gauge material (.001 - .002) is to be welded. Set control to mid-range for heavier gauge material (.006 - .008).

3. When making all welds, the ground electrode must be positioned with the tapered portion of the electrode held flat against the work material to obtain the best possible ground connection.

4. Depress the microswitch on spot weld handpiece.

Note: Make sample welds and pull test the material before attempting to make structural repair. The metal foil should fail before the weld nugget breaks.

Procedures for Seam Welding

1. Set SINGLE REPEAT switch to "REPEAT."

2. Set WELD POWER CONTROL switch the same as for spot welding.

3. The REPETITION RATE CONTROL switch allows the adjustment of welding speeds from 1 to 20 spots per second. Four to five spots per second is most desirable under normal welding conditions.

4. Depress the microswitch on the seam weld handpiece.

QUESTIONS

Note: Answer all questions on a separate sheet of paper. DO NOT WRITE IN THIS STUDY GUIDE.

1. What is hard surfacing?

2. What is the carbon range of the low and medium carbon steels that may be hard surfaced?

3. Can carbon steel above 0.50% carbon content be hard surfaced? What precautions must be taken?

4. Name three functions of hard surfacing.

5. What percent of alloying elements are found in the Group 1 hard surfacing material? Group 2?

6. In what group is Stoodex found? Stoodite? Stellite? Borium? Tube Borium?

7. What type of hard surfacing material is found in valve seats of internal combustion engines?

8. What hard surfacing alloys are generally used when parts are subjected to use in sand and gravel?

9. What is the transition bead method of applying hard surfacing?

10. Will carbon or metallic arc cutting produce as smooth a finish as oxyacetylene cutting?

11. What type of electrode is best suited for metallic arc cutting?

12. What is the approximate amperage setting for a 3/16" diameter electrode?

13. What polarity is used for carbon arc cutting? Metallic arc cutting?

14. How does the current setting compare between welding and cutting with a 3/16" diameter electrode?

15. Will the carbon arc cutting process satisfactorily cut armor plate?

16. What methods may be used to remove the scale and rough edges after cutting?

17. What two factors largely determine the current setting?

18. Is oxygen used in conjunction with some metallic electrodes for cutting? Explain.

19. What are the three important factors in resistance welding?

20. What is electrode contamination?

21. Why should spot welding electrodes be made of a special copper alloy?

22. Why is the timing so critical in welding stainless steel?

23. Does the welding of stainless steel require a higher secondary current than aluminum of the same thickness? Explain.

24. What will happen if the electrode radius is too small?

25. Why are short heat times necessary in welding titanium?

26. What is the purpose of insulation blankets?

27. How are mesh repair patches secured in place?

28. How is patching material cut to shape?

29. How are areas that have accumulations of hard-crusted material repaired?

30. What type of welding is used to attach patches to the foil?

31. Are any particular welding patterns used in blanket repair? Explain.

REFERENCES

TO 34W4-1-5, Welding Theory and Application, Modern Welding, Chapter 20.

ELECTRODE IDENTIFICATION AND OPERATING DATA

COATING COLOR	IDENTIFICATION MARKING (E) END	(S) SPOT	(G) GROUP	(-) SPECIAL	AWS CLASS	POLARITY DC (+) = "REVERSE" DC (−) = "STRAIGHT"	SIZES AND CURRENT RANGES (Amps.) (electrodes are manufactured in those sizes for which current ranges are given) 5/64" SIZE	3/32" SIZE	1/8" SIZE	5/32" SIZE	3/16" SIZE	7/32" SIZE	1/4" SIZE	5/16" SIZE
MILD STEEL														
White					E6010	DC (+)			75-130	90-175	140-225	200-275	250-325	280-400
Brick Red					E6010	DC (+)			75-130	90-175	140-225			
Tan		White			E6012	DC (−)		55-80	80-130	120-180	180-250	210-280	250-315	320-410
						AC		60-90	90-140	130-200	200-275	230-310	280-350	350-450
Gray		White			E6012	DC (−)			90-135	120-190	150-265	225-300	250-340	315-405
						AC			100-150	130-210	165-290	250-325	275-375	350-450
White		Blue			E6011	AC		40-75	75-120	90-160	120-200	150-260	180-300	
						DC (+)		35-70	70-110	80-145	110-180	135-235	170-270	
Dark Tan		Brown		Green	E6013	AC	40-75	65-100	90-140	140-200	200-280			
						DC (−)	35-65	60-90	80-125	125-180	180-235			
Gray Brown	Black	Brown			E7014	AC			110-160	150-225	260-[illegible]	260-340	315-425	370-[illegible]
					E6014	DC (−)			100-145	135-200	180-250	235-305	285-380	330-450
Tan					–	DC (−)				175-250	230-350	300-450		
						AC				160-225	210-315	275-410		
Tan		White		Green	E6012	DC (−)			80-135	110-180	155-250	225-295	245-325	
						AC			90-150	120-200	170-275	250-325	275-360	
Brown		Blue			E6011	AC		40-90	60-120	115-150	160-210			
						DC (+)		40-80	55-110	105-135	145-190			
Dark Gray	Black	Yellow			E7024	AC			130-190	190-250	240-300	300-380	360-440	
					E6024	DC (+)			120-180	180-230	220-280	280-360	330-400	
Red-brown		Silver			E6027	AC				190-240	250-300	300-380	350-450	475-600
						DC (+)				175-215	230-270	270-340	315-405	
Gray	Black	Yellow		Green	E7024	AC		65-120	115-175	180-240	240-300	300-380	350-450	450-600
					E6024	DC (±)		60-110	100-160	160-215	215-270	270-340	315-405	
Gray	Black	Orange	Green		E7018	DC (+)		70-100	95-155	120-200	160-280	190-310	230-360	375-475
					E6018	AC		80-120	115-165	145-230	200-310	240-350	290-410	400-500
Gray-Brown	Black	Black			E7028	AC				180-270	240-330	275-410	360-526	
					E6028	DC (+)				170-240	210-300	260-380		
LOW ALLOY, HIGH TENSILE STEEL														
Pink	Blue	White			E7010-A1	DC (+)		50-90	75-130	90-175	140-225		190-325	
Pink	Blue			Green	E7010-G	DC (+)					140-225			
Pink					–	DC (+)			75-130	90-175	140-175			
Dark Red	Blue	Yellow	Silver		E7020-A1	AC				190-240	250-300	275-375	350-450	
						DC (±)				175-215	230-270	250-320	330-370	
Gray				9018	E9018-G	DC (+)			90-150	110-200	160-280			
						AC			110-160	140-230	2[illegible]-310			
Gray				11018	E11018-G	DC (+)			95-155	120-200	160-280	190-310	230-360	
						AC			115-165	145-230	200-310	240-350	290-410	
STAINLESS STEEL														
Pale Green	Yellow		Black	308-15	E308-15	DC (+)	20-55	30-70	50-100	75-130	95-165		150-225	
Gray	Yellow		Yellow	308-16	E308-16	DC (+); AC	20-45	30-60	55-95	80-135	115-185		200-275	
Gray	Brown		Yellow	308L-16	E308L-16	DC (+); AC		30-65	55-100	80-140	115-190		200-285	
Pale Green	Red		Black	310-15	E310-15	DC (+)		30-70	45-95	80-135	100-165		140-225	
Gray	Red		Yellow	310-16	E310-16	DC (+); AC		30-65	55-100	80-140	120-185		200-275	
Gray	Brown	White	Yellow	316L-16	E316L-16	DC (+); AC		30-65	55-100	80-140	115-190		200-285	
Pale Green	Yellow	Green	Black	318-15	E318-15	DC (+)		30-75	45-95	80-135	100-165			
Pale Green	Yellow	Blue	Black	347-15	E347-15	DC (+)	20-55	30-70	50-100	75-130	95-165		150-225	
Gray	Yellow	Blue	Yellow	347-16	E347-16	DC (+); AC		30-60	55-95	80-135	115-185			
BRONZE & ALUMINUM														
Peach	Yellow	Blue	Blue		E-CuSn-C	DC (+)			50-125	70-170	90-220			
Peach					Al-43	DC (+)		20-55	45-125	80-170	85-235		125-360	
CAST IRON														
Light Tan	Orange				ESt	DC (+); AC			80-100					
Black	Orange	Blue	White		ENi	DC (±)			60-110	100-135				
						AC			65-120	110-150				
HARDSURFACING														
Black						DC (±)			40-150	75-200	110-250		150-375	
						AC			50-165	80-220	120-275		165-410	
Slate	Yellow					DC (+); AC					60-150			145-350
Slate	Pink					DC (+); AC					60-150			145-350
Gray						DC (+); AC				115-225	200-290		255-375	
Bare Wire						DC (+)					130-170		170-225	
Dark Gray	Orange	Red				DC (±)				125-210	150-260		200-350	
						AC				135-230	165-285		220-385	
Slate						DC (−); AC		40-85	65-130					
Gray						DC (+)			65-100					
Dark Gray						DC (+)					110-275		150-400	
						AC					125-275		200-400	

TABLE 1

Foldout 1.
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ELECTRODE IDENTIFICATION AND OPERATING DATA

COATING COLOR	IDENTIFICATION MARKING (E) END	(S) SPOT	(G) GROUP	(L) SPECIAL	AWS CLASS	POLARITY DC (+) = "REVERSE" DC (−) = "STRAIGHT"	SIZES AND CURRENT RANGES (Amps.) (electrodes are manufactured in these sizes for which current ranges are given) 5/64" SIZE	3/32" SIZE	1/8" SIZE	5/32" SIZE	3/16" SIZE	7/32" SIZE	1/4" SIZE	5/16" SIZE
MILD STEEL														
White					E6010	DC (+)			75-130	90-175	140-225	200-275	250-325	280-400
Brick Red					E6010	DC (+)			75-130	90-175	140-225			
Tan		White			E6012	DC (−)		55-80	80-130	120-180	180-250	210-280	250-315	320-410
						AC		60-90	90-140	130-200	200-275	230-310	280-350	350-450
Gray		White			E6012	DC (−)			90-135	120-190	150-265	225-300	250-340	315-405
						AC			100-150	130-210	165-290	250-325	275-375	350-450
White		Blue			E6011	AC		40-75	75-120	90-160	120-200	150-260	180-300	
						DC (+)		35-70	70-110	85-145	110-180	135-235	170-270	
Dark Tan		Brown		Green	E6013	AC	40-75	65-100	90-140	140-200	200-260			
						DC (−)	35-65	60-90	80-125	125-180	180-235			
Gray-brown	Black	Brown			E7014	AC			110-160	150-225	200-280	260-340	315-425	370-500
					E6014	DC (−)			100-145	135-200	180-250	235-305	285-380	330-450
Tan					–	DC (−)				175-250	230-350	300-450		
						AC				160-225	210-315	275-410		
Tan		White		Green	E6012	DC (−)			80-135	110-180	155-250	225-295	245-325	
						AC			90-150	120-200	170-275	250-325	275-360	
Brown		Blue			E6011	AC		40-90	60-120	115-150	160-210			
						DC (+)		40-80	55-110	105-135	145-190			
Dark Gray	Black	Yellow			E7024	AC			130-190	190-250	240-300	300-380	360-440	
					E6024	DC (+)			120-180	180-230	220-280	280-360	330-400	
Red Brown		Silver			E6027	AC				190-240	250-300	300-380	350-450	475-600
						DC (+)				175-215	230-270	270-340	315-405	
Gray	Black	Yellow		Green	E7024	AC		65-120	115-175	180-240	240-300	300-380	350-450	450-600
					E6024	DC (±)		60-110	100-160	160-215	215-270	270-340	315-405	
Gray	Black	Orange	Green		E7018	DC (+)		70-100	95-155	120-200	160-280	190-310	230-360	375-475
					E6018	AC		80-120	115-165	145-230	200-310	240-350	290-410	400-500
Gray-Brown	Black	Black			E7028	AC				180-270	240-330	275-410	360-520	
					E6028	DC (+)				170-240	210-300	260-380		
LOW ALLOY, HIGH TENSILE STEEL														
Pink	Blue	White			E7010-A1	DC (+)		50-90	75-130	90-175	140-225		190-325	
Pink	Blue			Green	E7010-G	DC (+)					140-225			
Pink				–		DC (+)			75-130	90-175	140-175			
Dark Red	Blue	Yellow	Silver		E7020-A1	AC				190-240	250-300	275-375	350-450	
						DC (±)				175-215	230-270	250-320	330-370	
Gray				9018	E9018-G	DC (+)			90-150	110-200	160-280			
						AC			110-160	140-230	200-310			
Gray				11018	E11018-G	DC (+)			95-155	120-200	160-280	190-310	230-360	
						AC			115-165	145-230	200-310	240-350	290-410	
STAINLESS STEEL														
Pale Green	Yellow		Black	308-15	E308-15	DC (+)	20-55	30-70	50-100	75-130	95-165		150-225	
Gray	Yellow		Yellow	308-16	E308-16	DC (+); AC	20-45	30-60	55-95	80-135	115-185		200-275	
Gray	Brown		Yellow	308L-16	E308L-16	DC (+); AC		30-65	55-100	80-140	115-190		200-285	
Pale Green	Red		Black	310-15	E310-15	DC (+)		30-70	45-95	80-135	100-165		140-225	
Gray	Red		Yellow	310-16	E310-16	DC (+); AC		30-65	55-100	80-140	120-185		200-275	
Gray	Brown	White	Yellow	316L-16	E316L-16	DC (+); AC		30-65	55-100	80-140	115-190		200-285	
Pale Green	Yellow	Green	Black	318-15	E318-15	DC (+)		30-75	45-95	80-135	100-165			
Pale Green	Yellow	Blue	Black	347-15	E347-15	DC (+)	20-55	30-70	50-100	75-130	95-165		150-225	
Gray	Yellow	Blue	Yellow	347-16	E347-16	DC (+); AC		30-60	55-95	80-135	115-185			
BRONZE & ALUMINUM														
Peach	Yellow	Blue	Blue		E-CuSn-C	DC (+)			50-125	70-170	90-220			
Peach					Al-43	DC (+)		20-55	45-125	60-170	85-235		125-360	
CAST IRON														
Light Tan	Orange				ESt	DC (+); AC			80-100					
Black	Orange	Blue	White		EN-	DC (±)			60-110	100-135				
						AC			65-120	110-150				
HARDSURFACING														
Black						DC (±)			40-150	75-200	110-250		150-375	
						AC			50-165	80-220	120-275		165-410	
Slate	Yellow					DC (+); AC					60-150			145-350
Slate	Pink					DC (+); AC					60-150			145-350
Gray						DC (±); AC				115-225	200-290		255-375	
Bare Wire						DC (+)					130-170		170-225	
Dark Gray	Orange	Red				DC (±)				125-210	150-260		200-350	
						AC				135-230	165-285		220-385	
Slate						DC (−); AC		40-85	65-130					
Gray						DC (+)			65-100					
Dark Gray						DC (+)					110-275		150-400	
						AC					125-275		200-400	

TABLE 1